Vol. 2 MAY, 1923 No. 5

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Published Monthly by the American Welding Society
33 West Thirty-ninth Street, New York

American Welding Society

OFFICERS FOR 1923-24

T. F. Barton, *President*
C. A. McCune, *Treasurer*
M. M. Kelly, *Secretary*
Wm. Namack, *Vice-President*
T. F. Orchible, *Vice-President*
W. A. Slack, *Vice-President*
A. V. Thompson, *Vice-President*
C. L. Jones, *Vice-President*

DIRECTORS

(Officers listed above are also members of the Board of Directors)

Term Expires 1924	*Term Expires 1925*	*Term Expires 1926*	*Section Representatives*
A. S. Kinsey	James Burke	C. A. Adams	Eric Ewerts
J. C. Lincoln	A. F. Jenkins	A. M. Candy	R. D. Malm
H. L. Nicholson	Hermann Lemp	C. J. Holslag	J. A. Seede
E. M. T. Ryder	H. I. Walsh	H. S. Smith	
H. R. Swartley	S. W. Miller	C. A. McCune	
E. Vom Steeg			
E. Wanamaker			
J. H. Deppeler			

PAST-PRESIDENTS

C. A. Adams (1919-20)
J. H. Deppeler (1920-21)
S. W. Miller (1921-22)
C. A. McCune (1922-23)

CHAIRMEN, STANDING COMMITTEES

Executive—T. F. Barton
Finance—C. A. McCune
By-Laws—Hermann Lemp
Meetings and Papers—A. G. Oehler
Membership—L. B. Mackenzie

W. Spraragen, *Editor, Journal*

American Bureau of Welding

(RESEARCH DEPARTMENT OF SOCIETY)

OFFICERS

C. A. Adams, *Director*
H. M. Hobart, *1st Vice-Director*
A. S. Kinsey, *2nd Vice-Director*
Wm Spraragen, *Secretary*

CHAIRMEN, RESEARCH COMMITTEES

Electric Arc Welding—H. M. Hobart
Gas Welding—S. W. Miller
Welding of Storage Tanks—J. C. Lincoln
Pressure Vessels—H. L. Whittemore
Standard Tests for Welds—F. M. Farmer
Welding Wire Specifications—C. A. McCune
Training of Operators—J. C. Wright
Resistance Welding—Hermann Lemp
Thermit Welding—J. H. Deppeler
Welded Rail Joint—G. K. Burgess
Specifications for Iron and Steel to be Welded—W. J. Beck

JOURNAL
OF THE
AMERICAN WELDING SOCIETY

Copyrighted 1922 by the American Welding Society.
33 West Thirty Ninth Street, New York.
Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00 Back numbers per copy, Members, $ .50; Non-Members, $1.00.
The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 2 May, 1923 Number 5

TABLE OF CONTENTS

SOCIETY AND RELATED ACTIVITIES PAGE

President Barton 3
Annual Meeting, American Welding Society 3
President's Report for Year's Activities 6
Section Activities 7
Employment Service Bulletin 11

TECHNICAL PAPERS, ITEMS AND REPORTS

WELDED PRESSURE VESSELS 11
Introduction 11
Recommendation to A. S. M. E. Boiler Code Committee 13
Comments on Construction 16
Design 22
Hydrostatic Hammer Test 28
Insurance 35
Physical Quality of Materials 36
Chemical Requirements of Plate 39
Welding Wire 41
Tests of Welded Specimens 42
Marking and Stamping 58
Bureau of Standards Report 62
Introduction 63
Description of Apparatus and Test Methods 64
Description of Tanks 66
Test Results 68
Discussion of Results 68
Conclusions 77
Metallographic Examination 129
CURRENT WELDING LITERTATURE 163

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce Street, Philadelphia Pa.

Chairman—Theo. F. Oechsle, Consulting Engineer, David Lupton's Sons Co.
Secretary—A. Schroeder, Standard Electric Welding Company.

CHICAGO

Peoples Gas Building, Chicago.

Chairman—H. A. Austin, Mfg Oxygen and Hydrogen.
Secretary—Harold W. Cook, Editor, Acetylene Journal Publishing Company.

PITTSBURGH

1841 Oliver Building, Pittsburgh.

Chairman—J. D. Conway, Secretary-Treasurer, Railway Supply Mfg. Association.
Secretary—H. E. Hollis, P. O. Box 681, Pittsburgh, Pa.

NEW YORK

33 West Thirty-ninth Street, New York

Chairman—E. H. Ewertz, Bethlehem Shipbuilding Co., Elizabeth, N. J.
Secretary—H. J. Grow, Air Reduction Sales Co., New York.

NORTHERN NEW YORK

Room 451, Building 2, General Electric Company, Schenectady

Chairman—H. M. Hobart, General Electric Co., Schenectady, N. Y.
Secretary—W. L. Warner, General Electric Co., Schenectady, N. Y.

CLEVELAND

2300 Chester Avenue, Cleveland Ohio.

Chairman—J. C. Lincoln, Lincoln Electric Company.
Secretary—R. K. Randall, Dean, Welding School, Cleveland School of Technology.

SAN FRANCISCO

Rialto Building, San Francisco.

Chairman—J. C. Bennett, Assistant Engineer, Associated Oil Co. San Francisco.
Secretary—W. B. Sawyer, Jr., United States Steel Products Company.

LOS ANGELES

451 East Third Street, Los Angeles

Chairman—L. J. Smith, District Sales Manager, The Ideal Electric & Mfg. Company.
Secretary—E. W. Crane, E. E., 1119 Santa Fe Avenue Los Angeles.

BOSTON

Engineers' Club, 2 Commonwealth Avenue, Boston, Mass.

Chairman—Thomas A. Wry, General Electric Company, Lynn, Mass.
Secretary—J W. Morrissey, P. F. McDonald & Company, Boston Mass.

AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

VOL. 2. MAY, 1923. NO. 5

BARTON ELECTED PRESIDENT

At the annual meeting of the American Welding Society, Mr. T. F. Barton, Master Mechanic of the Delaware, Lackawanna and Western Railroad was elected President for the coming year.

Mr. Barton was born in London, England, March 21, 1867, and came over to Canada when very young. He is essentially a railroad man, having started as call boy for the Grand Trunk

T. F. BARTON

in 1880, following which he served as Machinist Apprentice, Machinist, Assistant Round House Foreman, Round House Foreman, General Foreman, and Master Mechanic. At various times in his career he was connected with the following railroads, Grand Trunk, Illinois Central and Delaware, Lackawanna and Western railroad. He is an active member in the New York Railroad Club and Master Mechanic Association and was one of the pioneers in the welding field.

The Society is indeed fortunate to secure at this time the guiding hand of a man of Mr. Barton's ability, wide experience, connections, and standing in railroad circles. He is well known to us having served in the capacity of Chairman of the New York Section and more recently as Treasurer of the American Welding Society. Mr. Barton has been one of the most active in securing new members. The railroad with which he is connected through his efforts since last year has been able to report that all its welders are members of the Society.

ANNUAL MEETING OF AMERICAN WELDING SOCIETY

The Fourth Annual Meeting of the American Welding Society was formally launched with Committee Meetings on Tuesday Morning, April 24th and was concluded with an inspection trip on Friday afternoon, April 27th.

A meeting of the Committee on Training of Operators was held Tuesday morning April 24th. Work of this Committee during the past year and a half has been in drawing up an outline for a standard course on the Training of Oxy-Acetylene Welders and one for the training of Electric Arc Welders. The former has now been completed and was published in the April issue of the Journal and is also available in bulletin form. The one on the training of electric welders is nearing completion and will probably be published sometime during the summer. Those who are expert state that these courses are so well prepared that there can be no question but what they will be universally adopted throughout the country.

The Resistance Welding Committee also held its meeting Tuesday morning. In addition to the several reports already published there was reviewed a summary of the present state of the art of spot welding and one on seam weld-

ing. It is expected that these will be completed shortly. It was decided to undertake an investigation to determine what constituted the best weldable qualitites in iron and steel to be welded by the resistance welding process, including chemical and physical requirements. The compilation of reliable data on electrical energy and pressures required in the various forms of resistance welding to obtain satisfactory results will also be undertaken.

A meeting of the Electric Arc Welding Committee was held Tuesday afternoon. At this meeting it was reported that the summary on the present state of the art in the appplication of welding to shipbuilding was completed and will be published as a serial in Marine Engineering and later reprinted for the American Welding Society in bulletin form. Investigations were outlined and approved for the arc welding of nonferrous metals. Several new summaries will be undertaken including one on speed of welding.

At the meeting of the Committee on Welding of Storage tanks on Tuesday afternoon, it was reported two 1,000 barrel tanks had been constructed in accordance with the recommendations prepared by a Sub-Committee on Gas Welding. This report will be published in an early issue of the Journal. The one on electric arc welding appeared in the December 1922 issue.

The business session of the American Welding Society was held Wednesday, April 25th. President McCune reviewed the progress made by the Society during the past year and brought out that it was now in a stronger financial position than ever before, is better known and appreciated. The President's report is published elsewhere in the Journal. Reports by the Committees on Finance, Membership, and Meetings and Papers were also presented. The Meetings and Papers Committee report was published in the April issue of the Journal and the Finance, and Membership reports will be published in the June issue. The special feature of the business session was a review of the recent developments in the welding field, including those in electric arc, gas, resistance and thermit welding.

About forty members attended the inspection trip to the Third Avenue Railway Shops Wednesday Afternoon, April 25th. Demonstrations of metallic arc, carbon arc and semi-automatic metallic arc welding were given on truck side frames, plough yokes, and miscellaneous truck and body parts of street cars. Some of the members after witnessing the welding demonstrations made a general inspection of the shops and witnessed the variety of repairs necessary to keep the 1,600 cars of this street railway in working order.

The Second Annual Dinner of the Society was held in Park Avenue Hotel. The predictions of the Dinner Committee that a worth while get-together meeting and dinner would be provided was fully borne out. About 100 members were in attendance. Mr. E. H. Ewertz acted as Toastmaster. The special guests of honor were Harry Vought, Secretary of the New York Railroad Club and the Master Boilermakers Association; Mr. John H. Hayes, Secretary of the Compressed Gas Manufacturers Association, and Miss M. M. Kelly, Secretary of the American Welding Society.

The Annual Meeting of the American Bureau of Welding was held Thursday morning. It was brought out at this meeting that some 15 reports had been published during the past year and a half by its eleven research committees and that still others are in preparation. The special feature of the research work was the financing on a co-operative basis of a $15,000 investigation on pressure vessels and a $80,000 investigation on welded rail joints. A special Committee was appointed to consider the advisability of the Bureau undertaking sponsorship of a safety code on welding and cutting. The present officers were re-elected for the ensuing year.

The following appointments were made at the Board of Directors meeting Thursday afternoon, April 26.

Treasurer, C. A. McCune
Secretary, M. M. Kelly

Executive Committee:
C. A. McCune
E. H. Ewertz
C. A. Adams
E. M. T. Ryder
C. J. Holslag
H. S. Smith
A. S. Kinsey
T. F. Barton, Chairman

Membership Committee:
L. B. Mackenzie, Chairman
E. Vom Steeg
H. J. Grow
M. R. Feeley
F. M. McGinness

Finance Committee:
C. A. McCune, Chairman
E. M. T. Ryder
C. W. Bates
A. S. Kinsey
T. F. Barton

Meetings and Papers Committee:
A. G. Oehler, Chairman
C. J. Holslag
F. E. Rogers
W. Spraragen

Revision of By-laws Committee:
H. Lemp, Chairman

The Committee on Specifications for Steel to be Welded which held a meeting Thursday afternoon has undertaken the preparation of a symposium on what constitutes weldable and unweldable qualities of steel. Members of the Committee and others have agreed to prepare papers and articles setting forth their experience in the matter.

The Technical session of the American Welding Society was held Thursday afternoon. The two principle papers were "Welding of Unfired Pressure Vessels" by H. L. Whittemore, Chairman Pressure Vessel Committee and Chief, Structural and Engineering Materials Section of Bureau of Standards, and "Training of Welding Operators," by J. C. Wright, Chairman of Training of Operators Committee and Director, Federal Board of Vocational Education.

Both papers were well received and elicited considerable discussion. Mr. Wright explained the experience of the Federal Board of Vocational Education in planning training courses for industrial education, similar to that undertaken by the Bureau in Welding. Professor Whittemore outlined the results of the destructive tests of tanks at the Bureau of Standards.

The Gas Welding Committee, which held a meeting on Friday morning April 27th, outlined plans for its reorganization and appointed sub-committees to undertake investigations of the welding of pipe lines, manganese steel and duralumin.

A party of about thirty members of the American Welding Society met immediately after the meeting of the Gas Welding Committee on Friday, April 27th, and were conducted by Mr. L. E. Ogden, General Sales Manager, to the Oxweld Acetylene Company's plant on Frelinghuysen Avenue, Newark, N. J., where a delicious luncheon was served. Then the guests were conducted through the plant by Mr. C. K. Bryce, Works Manager, the Engineers and Department Superintendents of the Oxweld Company, first visiting the Engineering Department and inspecting the Machine Shop and Testing Laboratory, where the Oxweld Company investigates problems pertaining to oxy-acetylene apparatus. The visit to the Engineering Department was, of course, of great interest to the members of the Society as engineering of this nature is one of the important steps in the growth of the welding processes. The extent to which the Oxweld Company goes in its engineering work was quite a surprise to several of the visitors, particularly those who were more concerned with other processes than the Oxy-Acetylene. A visit was next made to the Tool Room where the proper tools were made for machining the different parts of Oxweld, Eveready and Prest-O-Lite torches and regulators; then the automatic and semi-automatic machines for making the various parts of the apparatus were inspected in operation, and finally, the party inspected and devoted considerable time to the study of the assembly and Testing Departments. All told, the visit in the works took approximately an hour and a half and it was quite noticable that those who were included in the inspection party seemed to find much of intest. The courtesy of the Oxweld Company in making this visit possible was much appreciated by the guests.

A Few of the Bound Volumes

of the

1922 Journal Still Left

$5.00 per copy

PRESIDENT'S REPORT OF YEAR'S ACTIVITIES

This Annual Meeting marks the ending of the fourth year of the existence of the American Welding Society and it is my pleasant duty to bid you welcome. Like other annual meetings the President's report may be summarized in one word PROGRESS.

Throughout the past year the wholehearted support of our members and the evidence of co-operation manifested by the general industries toward the Society, particularly that of the street railways, tank manufacturers, steam railroads and apparatus manufacturers were indeed gratifying and all that could be desired.

To the men who provide the equipment that makes welding possible (and without the apparatus there would be no need for our Society) will surely come the fruits of their loyal and generous support.

They are doing a noble work and are to be congratulated for the support they are rendering the Society and for the continuous development of high grade apparatus and materials, thereby lending their aid in welding education, assisting in the creation of welding standards and providing quality equipmnet with which to accomplish the work.

The monthly meetings of the sections have performed a tremendous good, both toward the practical side of welding and the further promotion of its human side, namely that of good fellowship. The condition today is such that it can be truthfully claimed that the Society is the real barometer of the industry.

The Society was organized during the period when welding took its first big leap forward and our membership consisted at that time of those only temporarily engaged in the art. These men have now entered other fields and their places taken by others who are permanently affiliated with the industry. It has, therefore, taken time for the Society to come to the settled and stabilized condition that exists today.

Our members realize more and more that by assisting in the work of the Society they are bound to benefit themselves. The general industries will support and co-operate with any organization composed of men whose general problems are in common with theirs, providing they can be shown that the accomplishments of the organization will prove of a material aid to them. As welding and cutting is a most important part of all metal joining indistries and the Society has proven its value to those interested in these fields, there is every reason to feel secure in the belief that within a comparatively short time the membership of the Society will be numbered by thousands. This can be accomplished by the efforts of our members and all that is required is plenty of enthusiasm. To acquire and possess this enthusiasm, the members must keep in close contact with the work of the Society, read the monthly journal and attend the monthly meetings.

The success of the Society is due to you men, who with the most sincere motives founded it, and who have earnestly helped it advance. You may well look upon your work with pride and satisfaction but you must impress new and prospective members with the fact that they will profit only to the extent of their earnestness.

I am happy to have the honor of having served you and while there were trying periods, I felt secure in knowing that your support and co-operation would be sufficient to help meet any situation. The reports of the Committees will verify this and although the contents of these reports are known and familiar to me, I will not anticipate them or take any liberty by quoting from them. They will be presented to you by the respective chairman.

However, you will be interested in a brief review of the work of your Executive Committee and Board of Directors. This review does not contain all the details as the committees' reports embrace a considerable part of the work of both the Executive Committee and the Board.

There were four meetings of the Executive Committee held during the year, the actions of which were all approved by the Board of Directors. Some of the more important issues discussed and acted upon were briefly as follows:

Joint Session of the American Electric Railway Association and the Society, October 5th 1922. This session was held during the Fall Meeting of the Society at Chicago and the following papers were presented:

Welded Rail Joints—E. M. T Ryder.

Welding Applications on Street Railways*—J. S. McWhirter.

*This paper was discussed and augmented by the Gas and Thermit Welding interests.

The meeting was of considerable benefit to the Society and while the two organizations were already co-operating through the work of the Welded Rail Joint Committee of the American Bureau of Welding, this meeting welded a stronger friendship.

The co-operation of the Acetylene Journal and the Welding Engineer was acknowledged with thanks. Both of these papers have greatly contributed to the publicity of the Society and in many other ways assisted in its promotion.

Mr. L. B. Mackenzie, Editor of the Welding Engineer, made arrangements whereby the Welding Encyclopedia was delivered to the Society at cost, thereby enabling the Society to realize considerable profit.

An attempt was made to reduce the cost of mailing the Journal by adopting second class mailing but the requirements of the postal authorities were such as to entail considerable bookkeeping and for the present this plan was abandoned.

Suggestions were made to eliminate the returns by the Society to Sections on Class D dues. The co-operation of the Sections is being sought so that this will be unanimously approved.

Complete plans were developed for the organization and operation of Sections. This also includes a standard skeleton section by-laws. These plans were typed and distributed to the Membership Committee and Vice-Presidents.

The publication of a membership directory was discussed and while there has been no appropriation for publication, the work of compiling a suitable directory is well under way.

A complete report of receipts, expenditures, membership, etc., is forwarded by National Headquarters to the Secretary of each section every month. It is intended that this report be read at the monthly meetings of the Sections.

A form was also devised upon which each section made a monthly report of its affairs.

These reports were complete and afforded the sections and national headquarters a full and true knowledge of existing conditions at all times throughout the year.

The New York Section passed a resolution as evidence of their co-operation in which it was resolved that providing National Headquarters agreed to provide the necessary help and materials for conducting the activities of the Section they were willing to forgo any returns on all dues until such time as the Society had more available funds.

This same spirit was also manifested by the Pittsburgh Section when they voluntarily offered if necessary to turn over all the money in their treasury—several hundred dollars—to meet any emergency for the good of the Society.

I trust this report or review will be encouraging to you as it truly signifies a thoroughly united body.

Sincerely yours,

C. A. McCUNE,
President.

SECTION ACTIVITIES

Philadelphia

The Philadelphia Section held a meeting on April 16th at which time the following officers were elected:

Chairman, Theodore F. Oechsle.

1st Vice-Chairman, Col. Royal Mattice.

2nd Vice-Chairman, Joseph Meadowcroft.

Secretary, A. Schroeder.

Treasurer, Clifford W. Bates

After the election of officers, Professor A. S. Kinsey presented his revised motion picture "Oxygen, the Wonder Worker." This was preceded by a demonstration of liquid air by representatives of the Air Reduction Sales Company. About 125 were present. It is planned that for future meetings, actual demonstrations of welding operations will be arranged.

Chicago

A meeting of the Chicago Section was held on April 6th. The program consisted of six reels of motion pictures of welding and cutting operations, taken in the plant of Messer and Company, Frankfort, Germany, and furnished to the Chicago Section for this meeting by Mr. M. K. Dunham, of Chicago. The pictures gave a general indication of the electric and thermit welding processes, then showed the development of equipment for gas welding, starting with the manufacture of carbide, the generation of acetylene, the production of oxygen by both processes, and the uniting of these two gases to produce the welding flame. The apparatus for the production of oxygen by the air liquefaction process was shown in operation.

This was followed by sectional views of various types of acetylene generators and the welding and cutting torches. The welding operations included the welding of vertical seams, straightening buckled sheets, repairing switches, building up rail crossings, boiler welding, copper welding, cast iron welding, steel cutting, rivet cutting, testing welds, and a series of views showing the usefulness of the cutting torch on a large scale in the work of dismantling a modern warship.

The May meeting was scheduled for May 4th at which time Mr. C. Wilkie was to present a paper on "Welding Ammonia Pipe Line Coils and Pressure Vessels." The paper was to be illustrated by lantern slides showing working drawings of welded joints and pipe.

Pittsburgh

The Pittsburgh Section held a very successful meeting in the Auditorium of the Chamber of Commerce Building on April 27th, 1923. The meeting was addressed by A. S. Kinsey, Professor of Shop Practice, Stevens Institute of Technology, on the subject of "Oxy-Acetylene the Wonder Worker." This picture was produced by the U. S. Bureau of Mines in co-operation with the Air Reduction Sales Company and illustrates how liquid air is made, why oxygen can be extracted from the air, how acetylene is made, how welding and cutting operations are performed, etc. About 125 people were in attendance including a number of ladies.

New York

According to the usual custom, the New York Section, as such, did not hold their regular April meeting as the technical session of the national organization has always been regarded as the April meeting of the Section.

The May meeting will be held in the Engineering Societies Building on May 15th. Mr. J. L. Anderson, Industrial Engineer of the Air Reduction Company will give a talk on "Production Welding of Sheet Steel by Oxy-Acetylene Processes."

Northern New York

At a meeting of the Northern New York Section of the American Welding Society, held at Union College on March 21, Mr. C. J. Holslag, Chief Engineer of the Electric Arc Cutting and Welding Company explained the "Theory of Alternating Current Arc Welding."

Mr. Holslag touched on the characteristics of successful arc welding, the relative advantages of flux covered electrodes and an explanation of the Holslag Arc Welding Transformers. Mr. Holslag's paper was discussed by a number of prominent engineers present.

The April meeting of the Section was held on the 24th, at which time Prof. E. A. Fessenden of the Mechanical Engineering Department of Renesselaer Polytechnic Institute, described some tests on welded cylinders that he had made for a company in Pennsylvania which manufactures ammonia containers for refrigerating plants. The speaker explained the service requirements of ammonia containers and stated that in the tests, four types of construction was tested. Two types of vessels were made of seamless steel pipe; one with convex dished heads, acetylene welded; the other with convex dished heads, forge welded. The other two types were flanged steel pipe with acetylene and forge welded heads. Professor Fessenden concluded from these tests that the cylinders made from seamless steel pipe with acetylene welded heads are the best. Slides were shown of the method of conducting the tests, the failure of the cylinders and photomicrographs of various sections of the welding. At this meeting the following officers were elected to serve for the coming year.

Chairman, H. M. Hobart
First Vice-Chairman, W. H. Namack
Second Vice-Chairman, J. C. Hoar
Secretary, W. L. Warner
Treasurer, E. J. O'Connell
Directors for four years:
S. R. Stockholm
G. W. Swan
Rep. on Board of Directors:
J. A. Seede

Cleveland

An informal get-to-gether meeting of the Cleveland Section was held in the Cleveland Engineering Society Rooms of the Hotel Winton on April 30th. The meeting was given over to a round table discussion of the program for the coming year, and research and other activities to be undertaken by the Section. At this meeting the election of the following officers was announced:

Chairman, J. C. Lincoln
Vice-Chairman, J. H. Thornton
Vice-Chairman, R. S. Sawdey
Treasurer, G. B. Close
Secretary, R. K. Randall
Chairman, Meetings & Papers Committee, H. H. Dyar

San Francisco

At the annual meeting of the San Francisco Section on April 20th, the following officers were elected:

Chairman, J. C. Bennett

Vice-Chairman, D. J. Will

Treasurer, K. L. Brackett

Secretary, W. B. Sawyer

Executive Committee Member, (3 year term) G. O. Wilson

Executive Committee Member, (2 year term) W. P. Brown.

Executive Committee Member, (1 year term) E. L. Curtiss

Los Angeles

The March meeting of the Los Angeles Section was held on the 8th, at which time Mr. W. P. Brown of the Brown Bros. of San Francisco explained with the aid of about 125 lantern slides the welding work turned out by his company. These slides illustrated the different uses for Oxy-Acetylene, electric arc and thermit welding.

Boston

The April meeting of the Boston Section was held on April 18th. About 150 were in attendance. The meeting was opened by an excellent exhibition of welded gear wheels, shaft worms and other representative mill parts presented by Mr. Thompson of the Arlington Mills, Lawrence, Mass. Their operator, Mr. Routh, then actually rebuilt a worn out worm shaft of 2 inch diameter with remarkable skill.

Following that Mr. McNamara of 80 Linden Street, Everett, Mass., gave a demonstration of lead welding or "lead burning" as it has been called. Mr. McNamara showed that this was a true weld and was dependable in every respect. This welding is done with a special "lead burning" torch and very low pressure is used.

The third demonstration was intended to show riser cutting on heavy steel castings, where risers might have thicknesses of 24 inches and more. The regular way to cut these risers would be to stand the casting upright and then cut the risers vertically. This, however, would mean that the traveling crane had to hold the casting which might be 12 feet in height, until all the many risers had been cut, thus making this crane unavailable for other work and obstructing the free passage of other cranes. The steel casting is therefore dropped flat with risers up and the cutting has to be done in a more or less horizontal plane. This means cutting open a much wider kerf and of course using more oxygen, which, however, is cheaper than stalling the cranes or even the foundry. Mr. E. A. Keough of the General Electric Company made an actual demonstration of cutting a steel block under the actual cutting conditions prevailing in steel foundries.

After this cutting demonstration, Professor Kinsey of the Air Reduction Company discussed briefly the problem of cutting cast iron and showed the aid of stereopticon slides the progress made in cast iron cutting. Mr. R. N. Rooke, Jr., then showed how this applied in practical cutting by making an actual cut on a block of cast iron with a cross section 13 inches by 15 inches. He used a special No. 7 tip for cutting Cast Iron and high pressure. Following this Mr. W. A. Webb of the Dover Stamping Company, Cambridge, Mass., explained the success which he had had in his plant in changing and building up by acetylene, tool steel dies, to be rehardened and tempered and used on the blanking of sheet steel. Mr. Webb had one of his welders give a demonstration of the method he employed and explained each step, how a special High Carbon Tool Steel Welding Wire, was used, how a very low flame was employed and great care used to protect the molten metal from the air, how special tools were made for peening the weld to refine the grain as much as possible, and finally he showed blanks which had been made with a welded die that had turned out as many as 150,000 blanks after being altered by welding. Mr. G. L. Walsh of the Interstate Welding Works, Worcester, Mass., then made an actual thermit weld of a pipe joint. The pipe used was 1¼ inch extra heavy; 2½ lbs. of thermit were used for making the weld which took eight minutes, including the assembling of the clamps, setting the mould, pouring the thermit and stripping the mould.

The next meeting, which is the final meeting of the season, will be held on May 16th. Mr. J. H. Deppeler, Chief Engineer, Thermit Department, Metal and Thermit Corporation, will present a paper on "Thermit Welding." The speaker will use slides and motion pictures to illustrate his talk. An actual demonstrations of thermit welding will be given. The last General Electric film, "Wizardry of Wireless," will be shown and there will be plenty of smokes and eats for everybody.

EMPLOYMENT SERVICE BULLETIN

To meet the demand of its members, the American Welding Society maintains an Employment Service Bulletin. The bulletin is divided into two sections—POSITIONS VACANT and SERVICES AVAILABLE. No charge will be made either to the available engineer, foreman or welder, or to the organization seeking welding talent. The number of opportunities for employment of which the Society has knowledge does not at present equal the number of men whose services are available. The co-operation of members of the Society, industrial establishments and others needing the services of men trained in the various branches of welding is earnestly desired. The location, necessary qualifications for each position and the approximate salary, if possible, should be stated in each case.

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the Thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

POSITIONS VACANT

V-10—Consulting Metallurgical Engineer who specializes in either soldering, brazing or welding. We are looking for a good consultant to help us on some of our problems.

Extra copies of the Pressure Vessel Report as given in this issue may be obtained in bulletin form at $1.50 per copy to members and $5.00 per copy to non-members.

AN INVESTIGATION OF WELDED PRESSURE VESSELS

INTRODUCTION

Events leading up to the Investigation. One of the important problems of the Boiler Code Committee of the American Society of Mechanical Engineers, has been the formulation of rules for the construction of unfired pressure vessels, which was part of the original program assigned to the Committee when it was appointed. Difficulty was experienced in preparing rules for the use of fusion welding, as the failures of a few welded pressure vessels had led some persons to feel that welded seams were inherently weak. The increased application of the method in the construction of tanks made it advisable to secure accurate information as to the strength of welded tanks.

It was necessary to proceed with caution as hasty or ill-advised regulations might work serious harm to the industries involved. The opinions of those who had experience with welding could not be easily reconciled either in regard to design, materials or workmanship nor to tests which would prevent unsafe tanks getting into service.

In March 1920, the Council of the American Society of Mechanical Engineers requested the American Welding Society and the American Society of Refrigerating Engineers to appoint committees to co-operate with the Boiler Code Committee in the preparation of that part of the Code which would deal with fusion welding. A tentative code was drawn up by these committees. Using this the Boiler Code Committee prepared a Code covering the points on which there seemed to be general agreement, together with an appendix containing questions covering matters on which there was a difference of opinion.

A public hearing was held on December 5, 1921, at which this tentative code was reviewed. At this hearing, many different opinions were expressed by those experienced in this field, but not enough experimental evidence was presented to solve the questions involved.

Realizing the need for more information, the American Bureau of Welding called a meeting on April 28, 1922, for the purpose of organizing the manufacturers of welded pressure vessels to deal co-operatively with the situation.

The Pressure Vessel Committee of the American Bureau of Welding was formed with the following members:

H. L. Whittemore, Bureau of Standards, *Chairman.*

C. A. Adams, Harvard University.

J. P. H. de Windt, Steam Boiler & Fly Wheel Service Bureau
L. K. Doelling, De La Vergne Machine Co.
E. J. Flocke, The Vilter Manufacturing Co.
H. W. Heinrich, The Travelers Insurance Co.
G. H. Lane, York Manufacturing Co.
S. W. Miller, Union Carbide & Carbon Research Laboratories
W. B. Miller, The Pfaudler Co.
R. E. Wagner, General Electric Co.
W. Spraragen, National Research Council, *Secretary.*

On July 20th, 1922, the Secretary of the American Bureau of Welding obtained the co-operation of the Bureau of Standards. A meeting of the Pressure Vessel Committee was held on August 17, 1922 at which Professor H. L. Whittemore, Chief, Structural and Engineering Materials Section, Bureau of Standards, was elected Chairman and Mr. William Spraragen, Secretary, Division of Engineering, National Research Council, Secretary. The work to be done was also planned including the size and number of tanks to be furnished by each manufacturer. The instructions for making these test tanks were sent out on September 5th and within a short time the tanks arrived at the Bureau of Standards in Washington. During the latter part of November, preparations for making the tests were completed. The tests were started on December 4th, 1922, and completed on February 1, 1923.

ACKNOWLEDGEMENTS

The following companies co-operated in the investigation.
Brunswick-Kroeschell Co., New Brunswick, N. J.
Coast Culvert and Flume Co., Portland, Oregon.
De La Vergne Machine Co., New York, N. Y.
Elyria Enameled Products Co., Elyria, Ohio.
The Pfaudler Co., Rochester, New York.
Union Carbide & Carbon Research Laboratories, Inc., Long Island City, New York.
Vilter Mfg. Co., Milwaukee, Wis.
York Manufacturing Co., York, Pa.
Travelers Insurance Co., Hartford Conn.

The committee is specially indebted to Mr. S. W. Miller and Professor H. L. Whittemore for their supervision of the tests of the tanks and their assistance in the preparation of this report. Valuable assistance was also rendered the Committee by the following:

Mr. W. J. Beck, Director and Mr. J. H. Nead, Metallurgist, American Rolling Mill Co., Middletown, Ohio; Mr. H. W. Heinrich, Engineer, The Travelers Insurance Co., Hartford, Conn.; Mr. E. R. Fish, Chairman of the Pressure Vessel Committee of the Boiler Code Committee; Mr. C. W. Obert, Secretary of the Boiler Code

Committee; Mr. P. H. de Windt, Manager of the Steam Boiler and Fly Wheel Inspection Bureau, Hartford, Conn. Acknowledgement is also made of the interest shown and assistance rendered by Dr. F. C. Brown, Acting Director of the Bureau of Standards.

The tests were made and the Bureau of Standards report prepared by Dr. L. B. Tuckerman, Physicist, and Mr. M. E. Weschler and Mr. J. F. Scanlon, Research Associates, Bureau of Standards. The excellent photographs of the tanks were prepared by Mr. R. Davis and Mr. H. M. Brown of the Bureau of Standards. Mr. H. S. Rawdon, Physicist, Bureau of Standards, Washington, D. C., made the metallographic examination.

RECOMMENDATIONS

The following recommendations are made by the Pressure Vessel Committee of the American Bureau of Welding for the consideration of the Boiler Code Committee of the American Society of Mechanical Engineers in their revision of the Code for Unfired Pressure Vessels. It is the desire of the Pressure Vessel Committee to present in definite form the results of recent tests and suggestions for the revision of the code which are based on the most reliable information available at this time—much of which has not previously been brought to the attention of the Boiler Code Committee.

The Bureau of Standards report including descriptions of testing methods, test data, microscopical examinations and conclusions are given as Appendix A.

The recommendations are stated briefly below. They are then followed by an analysis of test data which led to their formulation.

1. Remove restrictions on welding in Section U 88 with regard to longitudinal seams, contents of vessels and pressures.

2. Reword Section U 93 as follows:

   The maximum working fiber stresses for fusion welded pressure vessel shall be:

   For steel plate, (complying with specifications in Section U-100), ... 8,000

   For Ingot Iron, ... 7,200

   If allowed by Code for { wrought iron pipe, ... 4,000 / steel pipe, lap welded, ... 7,200

3. Omit all welding wire specifications, but insert as Section U-95 the following:

   "The welding wire used shall flow freely and smoothly and shall not exhibit detrimental phenomena (such as undue sparking, boiling, etc.) during welding."

4. Omit Sections U-94 and U-96 for the sake of simplicity.
5. Alter Section U-97 to—
   "U-97—Material. Steel plate used for Class A and Class B Vessels shall not exceed $\frac{5}{8}$ inch in thickness, shall be made by the open hearth process, and shall be of good weldable quality, and free from defects that would impair its usefulness. With the exception of Ingot iron plate, which may be used subject to the Code, it shall conform to the following requirements:"
6. Change Section U-98 to
   U-98—Chemical Composition.

Carbon, not over	.15%
Manganese	.30 to .60%
Phosphorus, not over	.04%
Sulphur, not over	.05%

   (Omit all reference to chromium, silicon and nickel).
7. Change Section U-100, paragraph (a) as follows:
   "U-100. Tension Tests:
   Tensile strength max. lb. per sq. in. 55000
   Yield point min. lb. per sq. in. ..... $\frac{\text{T. S.}}{2}$
   Elongation in 8 inches, min. per cent ..... $\frac{1{,}500{,}000}{\text{T. S.}}$

The elongation of plate $\frac{1}{4}$ inch thick or less, shall be measured on a gage length of 24 times the thickness."

8. Add to Section U-101 all the details of the various items mentioned.
9. If possible, devise ways to simplify the routine of inspection and makers' reports.
10. Change Section U-102, 1st paragraph, as follows:
   (a) "U-102—Method of welding. All longitudinal seams shall be of the 90° double V type. Girth and head seams may be of 90° single V type. Double V welds shall be reinforced to a total thickness of at least $1\frac{1}{2}$ times the plate thickness at the center of the weld. Single V welds need not be reinforced more than 20% of the plate thickness at the center of the weld.
   (b) All the welds shall be of sound metal, thoroughly fused to the sides of the V its entire depth. The sheets must not be allowed to lap during welding.
   (c) When the thickness is $\frac{1}{4}$ inch or less, beveling of the longitudinal seams may be omitted, and when the thickness is less than $\frac{1}{4}$ inch, girth and head seam need be beveled on one side only, to an angle of 45°."
11. Alter Section U-105 as follows:

(a) "Dished heads convex to the pressure shall be a driving fit in the shell, and applied as in Figure 1a.

(b) The minimum length of skirt for both convex and concave heads shall be as follows:

Inside dia. of tank	Min. straight length of skirt.
12 inches and less	1¼ inches
over 12 inches to 24 inches	1¾ inches
over 24 inches to 36 inches	2¼ inches
over 36 inches to 48 inches	2¾ inches
over 48 inches to 60 inches	3¼ inches

(c) Heads concave to the pressure shall be butt welded to the shell, as in Figure 1b.

(d) In all cases where the head is over ¼ inch thick, and thicker than the shell by more than 1/16 inch, it shall be reduced to the shell thickness as shown in Figure 1a and b.

(e) Omit the requirements for crimping.

12. In Section U-107 making the use of the design shown in a, Figure U-3 permissive instead of compulsory.

13. Change Section U-108, 1st paragraph, as follows:

(a) "U-108—Nipples. Nozzles, nipples, or pipe connections may be applied as shown in Figure 1 and Table 5. Other equivalent constructions may be used. All pipe nipples welded into shells shall be of extra heavy pipe thickness, and those with shouldered ends may be either machined, or made by flaring the end of extra heavy pipe."

Table 5

Style	Shell dia.	Shell thickness	Pipe size	max. working pressure
c Fig. 1.	any	any	12 in. max.	any
d Fig. 1.	16 in. min.	3/16 in. min.	1 in. max.	any
d Fig. 1.	30 in. min.	¼ in. min	1½ in. max.	any
d Fig. 1.	48 in. min.	⅜ in. min.	2½ in. max.	any
e Fig. 1.	any that can be welded inside	any	8 in. max.	any
f Fig. 1.	any that cannot be welded inside	any	4 in. max.	250 lbs.
h Fig. 1.	any that can be welded inside	any	8 in. max.	any
k Fig. 1.	any	any	2 in. max.	150 lbs.

(b) The size and radius of fillet on outside of shell shall be as shown in Figure 1g.

(c) Nipples welded into tanks may be threaded internally or externally for pipe connections."

(d) Omit the part of paragraph 2, Section U-108, beginning at "Threaded nipples," and ending at "shown at (e) Figure U-3."

(e) Omit the countersink around nipples shown in d and e, Figure U-3, and use instead K, Figure 1.

14. Retain the hydrostatic hammer test as in the code, and add the following to Section U-109.

> "After this test the pressure shall be raised to 3 times the working pressure and held there 3 minutes, except in the case of vessels of special construction such as shell and tube brine-coolers, condensers, inter-coolers, etc. in which case the pressure shall be raised to 2 times the working pressure."

Analysis of Test Data Given in Bureau of Standards Report (Appendix A).

COMMENTS ON CONSTRUCTION

A tanks. These tanks have shells made of pipe, of a thickness of .563 inches, or 9/16 inches, which would be good for 375 lbs. working presure, on the same basis that the 3/8 inch welded shell tanks are good for 250. The physical tests and chemical analysis of the material would seem to warrant using that basis.

The Code formula for thickness of heads concave to the pressure is $t = \frac{PL}{20.000} + \frac{1}{8}$, which gives .555 inch in this case. A convex head would be by the Code 1 2/3 times this, or .925 inch. As these heads are 1 inch thick, they meet the Code requirements. They also are applied as called for by the Code. They stood pressures of 1710 lbs. maximum, and 1200 minimum, giving a factor or safety of 4.55 and 3.2.

At 250 lbs., their designed working pressure, these factors of safety become 6.8 and 4.8 respectfully, and under this working pressure it would seem from the tests that they would be perfectly safe. Their principal method of failure was in the electric head weld. It is easily noticed in the photographs that the heads bulged outward, increasing the diameter of the shell at the end, and putting a stress on the weld that increased its circumferential length, causing it to crack in spite of its heavy section. The greatest stress on the weld is the shearing stress parallel to the shell. If these welds were 3/4 inch long in the direction of shear, the factor of safety against shear is about 15, using 30,000 pounds per square inch as the ultimate shearing strength of the weld.

The B tanks were submitted by one maker as representing his standard practice, and tests on them gave some interesting results. The shells are all of pipe, and in tanks B1 and B2 are of wrought iron as shown by the chemical analysis. (Note the high phosphorus and silicon and low manganese.) Both of these split longitudinaly at low fibre stresses, which is natural, as the transverse strength of wrought iron is low, and as the width of the skelp from which the pipe is made is the circumference of the pipe.

The design of the heads does not comply with the Code, which requires that heads concave to the pressure "shall be attached to the cylinder by a butt weld," and that they shall have a skirt "not less than 3 inches long." Obviously such a length of skirt is unnecessary for tanks having diameters of from 8 inches to 12 inches, and would be expensive to make. The tests of these tanks, B1 and B2, show factors of safety, based on the maker's working pressure of 250 lbs., of 10.3 and 12.8. It therefore seems clear that the Code requirements need not be so severe in such cases, where the tanks are small, and the factors of safety are so high. However, it is felt that the design is not economical. A tank 8 inches diameter would only need to be ⅛ inch thick for 250 lbs. pressure, based on 8,000 lbs. working fibre stress, though the Code requires a minimum thickness of 3/16 inches. A 3/16 inch head concave to the pressure would meet the Code requirements. Using these last figures a tank could be made that would weigh less than half that of the present design. The same analysis applied to the 10 inch and 12 inch tanks, B2 and B3, shows the same general result.

It is realized, however, that conditions, such as nature of shop equipment, cost, etc., may change the aspect of the matter, and as the tanks have stood the test well, and seem to be entirely safe, the best of reasons should be assigned if the design of the B tanks is not to be allowed.

There is one principle which it is felt should be carried out in all welded steel structures of importance, which is that the included V angle should not be less than 90°.

The shells in these tanks were crimped over the heads, a construction that is thought by many to give added strength. There is some doubt, however, as to its effectiveness, though this must increase as the diameter of the tank decreases, the thickness of the shell and the amount of crimping being the same. The drawing of these tanks submitted by their maker shows such an amount of crimping, as to make the V angle so small, that it is quite impossible to make the weld as shown. The photograph of the actual sections shows this to be true, and it seems clear that considering the small amount of weld metal actually holding, and the fact that there is bad bending action on the weld, the very high factor of safety is all that saves the construction from failure, and so the design cannot be commended. It is believed that other designs, more efficient, and probably just as cheap, are available, and that

they should be used in the interests of safety. Of course there can be no objection to the use of pipe for the shell with a proper factor of safety, and with flanged heads butt welded to the shell, the construction would be beyond criticism.

Tank B3 blew the head off, most of the rupture being in the shell next the weld. The analysis of the shell indicates inferior steel. Another analysis was made at the Union Carbide & Carbon Laboratories, which gave the following:

Carbon	.07%
Manganese	.20%
Phosphorus	.057
Sulphur	.023
Silicon	.01

This would seem to indicate that the steel is not uniform and raises the question as to whether it is good policy to use pipe for pressure vessels unless its quality is assured.

It is possible that the high phosphorus is at least partly responsible for the character of the fracture, as phosphorus makes steel cold short. The fibre stresses given in Table 2 of the Bureau of Standards report, (Appendix A), are those in the shell. The stress in the head seam is half of this figure, within the elastic limit. In the case of tank B3, the head seam stress at failure was about 16,000 lbs. per square inch, as found from the sectional area of the shell and the pressure against the head. This is very low, and the failure is not easy to account for on the grounds of high phosphorus and possible welding strains.

The microscope shows that this steel is very dirty and, in the judgment of those who examined it, unfit for welding. This is probably the main reason for failure at such a low fibre stress.

The C tanks were of the same type of head construction as the B, but not crimped, and the shells were welded plate and not pipe. The average shell thickness was .361 inch, and the head thickness $\frac{5}{8}$ inch.

The shell would be allowed, with a fibre stress of 8,000 lbs., a working pressure of 240 lbs. The Code would require a head thickness, concave to the pressure, of .413 inch, so the head is amply strong.

The rather low fibre stresses at rupture were largely due to the imperfect fusion between the shell and the weld metal, which was the same in all 3 tanks. See Bureau of Standards, Figs. 16 and 17. This lack of fusion is also shown by the very low pressure at which leakage began. The heads were not crimped, so there was a greater space between the head and the shell than in the B tanks, but still the V angle was much less than 90°, and so the same objections apply here as in the B tanks.

The stress on the head seam was only about 19,000 lbs. per sq. in. of shell section, which is too low to cause any distortion or rupture in a properly made weld.

D tanks. These had pipe shells. The average shell thickness was .381 inch, which would allow a working pressure of about 260 lbs. For this pressure the head should be .437 inch thick, and as they were ½ inch thick the Code requirements are satisfied.

The method of attaching the heads to the shells was not in keeping with the Code. This of course does not condemn the method, and in D1 the pressure and fibre stress at rupture were high, factor of safety being 6.2. In D2 and D3, however, the rupturing stresses were much lower. In D2, the gage pipe froze up and the bursting pressure could not be determined, but from the method of failure it is evidently lower than D1. The observers, including a member of this committee, felt that the pressure at failure was not over 800 lbs.

It can be seen clearly that the ends of the shells of D2 and D3 were thinned down where they were crimped over, being in places about ¼ inch thick. The welds were evidently thinner than needed, and they broke under the strain.

The welds in D1 were much heavier, and it failed at 1,600 lbs., a factor of safety of 6.4, and as the welds did not give way, it would seem that this type of construction should be given careful consideration.

There is, however, an objection to this construction in that it brings together for welding a thick piece, which must be heated some distance from the edge, and a thinner piece, (even when full thickness) which is to be heated at the edge. The latter arrives at the fusion point first, and it is a hard matter for the welder to get equal fusion, and it is difficult to get fusion close to the edge of the shell next the head, which is desirable.

Also there does not seem to be much resistance offered by the crimping, though this may be due to a poor fit between the shell and the knuckle of the head. It appears that the shell had not been heated far enough back to get a good fit.

The F tanks all failed in the single V longitudinal seams. The shell and head thicknesses were ample for 270 lbs. working pressures. F3 had a spot about 3 inches long which was only welded about half through, failure evidently occurring here first. This defect seems to account for the low bursting pressure.

There seems to be no room for doubt that if the seam had also been welded on the inside, it would have stood a much higher pressure.

The design of these tanks is good, and meets the requirements of the Code.

The G tanks were allowed by the maker, 150 lbs. working pressure. The shell thickness was sufficient for 240 lbs., but the heads were only ⅜ inch thick, (nominal) which would reduce this pressure to about 208 pounds, so that the maker's rating was conservative, and complies with the Code.

Tank G2 was one of the strongest tanks in the lot, failing at 1,660 lbs. with a factor safety of 6.64, at 250 lbs. working pressure, or of 11.0 at the maker's rating. It had also the greatest amount of distortion, an increase of 6⅝ inch in circumference or about 9%.

Figure 30, Bureau of Standards, shows that there was a severe strain on the head weld caused by its rigidity, which kept it from bending, while the material on both sides of it could distort.

Tanks G1 and G3 failed at lower stresses than G2. The factors of safety, based on 250 lbs. working pressure, were 5.6, which would seem to be plenty high enough for safety. They seem to have some minor defects in the welds, which would account for their lower strength than G2.

The H Tanks complied with the Code in design, and were suitable in strength for 250 lbs. working pressure on the previous basis.

H1 gave the highest strength of any single V weld, and had a factor of safety of 6.3.

H2 was not so good a weld, though its factor of safety was 5.2

H3 had the greatest strength of any weld in the series, with a factor of safety of 7.2. It was a double V weld.

The K Tanks also complied with the Code in design, and were safe for working pressure of 250 lbs., at which they were rated by the maker. The heads were thinned for ⅜ inch in length at the end of the flange, to the shell thickness, for ease in welding.

K2 failed because of a split about 3 inches long in the weld. After this was cut out, it was found that this length was not welded inside, on one side.

K1 and K3 failed just outside the weld, with a few inches running part way into the weld.

K1, K2 and K3 were each welded with a different welding rod, the three varying widely in chemical composition, and K4 was an electric weld, a still different wire being used. It is rather remarkable that under these conditions there is less than 4% differences in the fibre stresses between the maximum and minimum.

The longitudinal welds were all double V, and all failed at from 1600 to 1660 lbs. The fibre stresses, based on actual shell thickness, varied from 50300 to 52000.

K4 is here included at the retest figure, as this is evidently the real strength of the tank.

K4 was electrically welded. It was tested, as usual, to 375 lbs. static pressure, showing no leaks. The pressure was then dropped to 250 lbs. and the shock test proceeded with. At 300 lbs. under the hammer, one of the head welds cracked for an apparent length of about 3½ in. Of course there was no distortion at this pressure The crack is shown and explained by Bureau of Standards Figures 7 and 59 and the description accompanying them. The crack was very fine on the surface, as shown by the photograph,

and is evidently the result of welding stresses. While it cannot be so stated positively, it seems from an examination of the vicinity that the wide end of the crack is at the beginning, (or end) of the welding, or at a place where some welding had been done after the seam had been made.

The maker reports that during the 50 lb. hydrostatic shop test for tightness, there were found two damp spots, one in each head seam, which were rewelded, and after retest were found tight. It is not possible now to identify these spots, but the crack may be at one of them.

This rewelding might account for a local stress, which, added to the test stress, might be of sufficient amount to cause local rupture. It is a very good illustration of what may occur if enough care be not taken in making repairs.

The defective piece was drilled out for examination, another piece fitted in, and welded electrically, after the metal in the neighborhood had been preheated with a welding torch to a very dull red, just visible in a poorly lighted room.

The preheating temperature was not allowed to fall during the welding, but was kept up by applying the torch as was necessary, and after welding, the spot was reheated to the same dull red, and allowed to cool in the open air, which was at about 70°F.

The method of repair is shown in Bureau of Standards Figure 59. After the repair the retest was made in the usual way, the tank standing a pressure of 1630 lbs., or a factor of safety of 6.6 based on the pressure.

There are three points to note in this connection.

1st. The static test at 1½ times the working pressure did not detect the defect.

2d. The defect was found by the hammer at a lower pressure than 1½ times the working pressure.

3d. The crack was evidently caused by local internal stresses because—

a. it occurred at low pressure.

b. it was local.

Conclusions: So far as this case is concerned, it seems clear that something more than a static test is needed, and that a shock of moderate amount while the tank is under moderate pressure will show up defects not revealed by a static pressure of the same or somewhat greater amount.

It is probably a good thing that this tank failed as it did, as it shows that the Code provision for a reweld and retest is safe practice if the work is properly done.

It is also evident that local stresses can exist in otherwise properly welded tanks, and that they have no effect on the strength of the rest of the welds.

DESIGN

There has been some reference to design in the discussion of the construction of the tanks tested at the Bureau of Standards, the conclusion being that the best method for applying heads is by butt welding a flanged head to the shell, and that where a head convex to the pressure is used, the method in the Code should be followed.

But while these conclusions seem justified by the tests, there are other important details that should be considered.

The first one is, what fiber stress should be used in designing unfired pressure vessels?

The tests show that the average bursting fiber stress of all double Vee welded tanks, (including the retested ones, but excluding the "fair" special tanks) was 53750, or over 101% efficiency. The Bureau of Standards report shows that the average efficiency of the double Vee welded regular tanks was 97%, and the minimum 90%. The Committee used a somewhat different basis from the Bureau of Standards but in both cases the the minimum was 90%.

The Code specifies 55000 as the maximum Tensile Strength. This is the minimum tensile strength of Boiler Code steel, and the Code provides that where such steel is used for riveted vessels, a maximum fibre stress of 11000 shall be used, which means a factor of safety of 5. The tensile strength of all the regular plate tanks material, except the C tanks, was; maximum, 52300; minimum, 48700; average, 50100.

The tensile strength in each case is given for completeness, as follows:

F1	49100	H1	49200
2	48900	2	48700
3	48900	3	49900
G1	49400	K1	52300
2	49800	2	52870
3	49900	3	51000
		4	51500

The minimum is only 2.8% less than the average. It seems quite fair and safe, therefore, to use 50000 lbs, as the basis for design. With a factor of safety of 5, and a weld value of 80%, this would mean a design fiber stress at the working pressure of 8000 lbs., based on the nominal plate thickness. In view of the high efficiency of the double Vee weld, 97% or 9700 lbs. fiber stress, using the above basis, this does not seem to the Committee excessive, unfair or in any degree dangerous, and they therefore recommend its adoption. It would apply also to the special tanks, only 4 of the 23 having less than 50000 tensile strength.

If the Code Committee thinks that wrought iron pipe should be allowed for pressure vessels, it is recommended that a maximum

working fibre stress of 4000 lbs. be used in design. The present Committee feels, however, that steel pipe is just as easy to obtain and much safer.

The restrictions in Section U-88 seem inconsistent to the Committee. An air tank is only allowed 150 lbs. while ammonia tanks are allowed 250. The latter is more dangerous, and both must be provided with suitable safety devices by Section U-2 of the Code.

Further, the Committee believes it is entirely safe to put all liquids or gases on the same basis as far as welding is concerned. That is, a vessel that is safe for ammonia is safe for any liquid or gas, if it is protected by proper safety devices; and no pressure vessel is safe without them, for any liquid or gas.

Also the Committee feels that Section U-88 should be so modified as to allow any pressure otherwise permitted by the Code, which limits the allowable plate thickness, and so the pressure. For instance, a tank $\frac{5}{8}$ inch thick and 24 inches diameter would only be good for 416 lbs. working pressure, which does not seem excessive.

The proposed fibre stresses for wrought iron pipes were arrived at as follows:

The proposed A. S. M. E. rules for piping and fittings specify 45000 as the minimum tensile strength of open hearth material for pipe. This being the same as the tensile strength of ingot iron, it would seem fair to use the same fiber stress for steel pipe as for the ingot iron, which would be 7200 lbs. based on a factor of safety of 5 and 80% weld value.

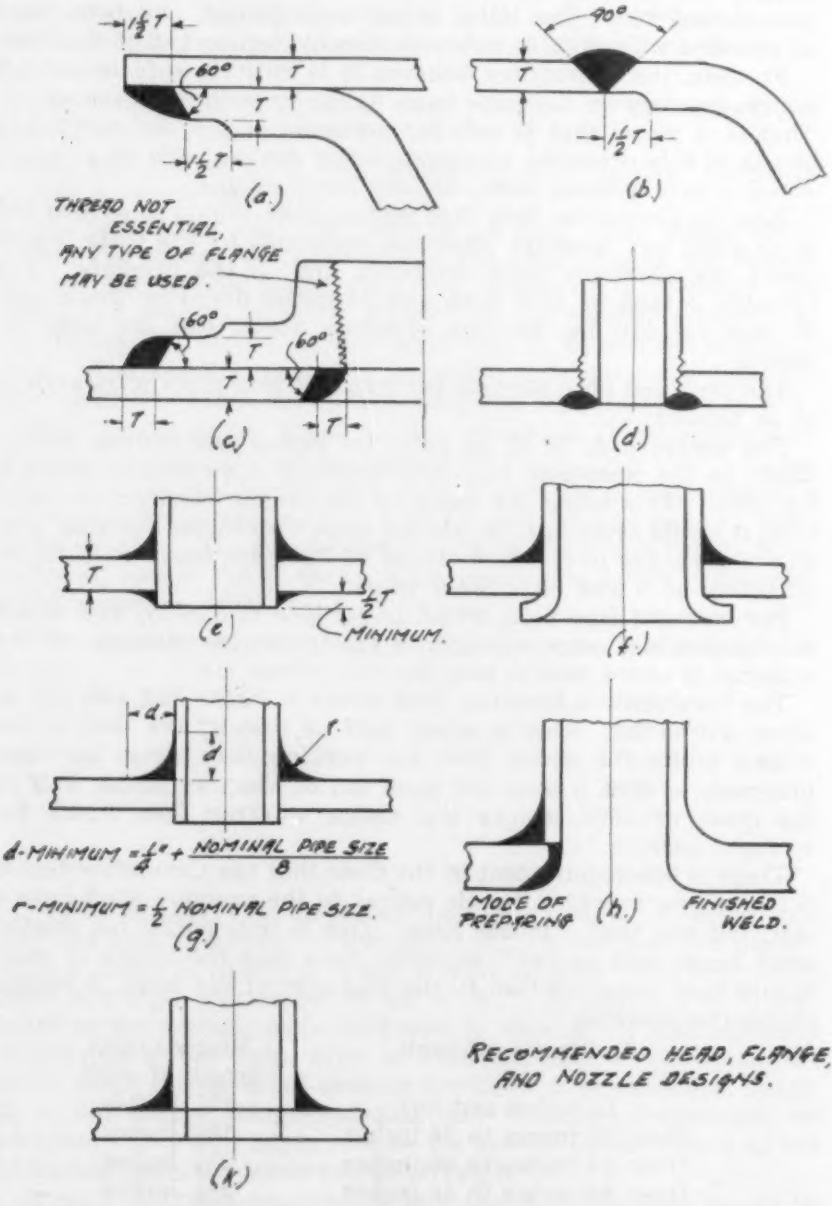
For wrought iron pipe, which is variable in quality, and where the longitudinal seam strength is the transverse strength of the material, it seems wise to keep the fiber stress low.

The tests show a bursting fiber stress in tanks B-1 and B-2 of about 25000 lbs. This is about half of that of the double Vee welded tanks, for which 8000 lbs. working fibre stress has been proposed, so that it does not seem out of the way to use half of the 8000, or 4000 lbs. as the design working fiber stress for wrought iron.

There is one requirement in the Code that the Committee thinks is too severe, in which "heads convex to the pressure shall have a skirt not less than 3 inches long. This is impractical for smaller sized heads, and as the Committee feels that the length of skirt should bear some relation to the diameter of the head, it recommends the following:

Inside dia. of tank	Min. straight length of skirt
12 inches and less	$1\frac{1}{4}$ inches
Over 12 inches to 24 inches	$1\frac{3}{4}$ inches
Over 24 inches to 36 inches	$2\frac{1}{4}$ inches
Over 36 inches to 48 inches	$2\frac{3}{4}$ inches
Over 48 inches to 60 inches	$3\frac{1}{4}$ inches

for both concave and convex heads, as being about what is found in practice. It may be pointed out that up to the yield point there is no stress on the weld of a convex head, except shear, and that any length of a skirt that insures this condition is enough. Also



RECOMMENDED HEAD, FLANGE, AND NOZZLE DESIGNS.

Figure 1.

that with a concave head, the first part to show yield point stresses is near the knuckle where Luders lines appear in the scale, so that here again any reasonable practical length is sufficient, anything longer not making the tank any stronger. Another point is that it would be well, the Committee thinks, to be somewhat more definite in the working of Section U-105, and to give diagrams showing just what will be allowed, for the benefit of the designer and inspector. It therefore recommends insertion of something like Figure 1a and b, with definite dimensions for the points covered in Section U-105.

The committee believes that the constricting or crimping of the end of the shell is unnecessary, and therefore should not be required. The tests did not include any tanks made as the Committee sees that the wording of the Code may be interpreted. (This may be either that only the end of the shell outside of the weld is to be crimped, or that the end of the shell, the weld and part of the skirt are all to be closed in together). But in neither case can the Committee see the need of crimping. In neither the Bureau of Standards tests, Professor Roark's tests, nor in those by Professors Fessenden and Bradford, is there any evidence to show that crimping is advantageous. A few figures will also show this.

Using the following notations:

t = shell thickness, inches.
L = length of weld in direction of shear, inches.
T = tensile strength of shell, lbs. per square inch.
S = shearing strength of weld, lbs. per square inch.
d = diameter of shell, inches.
p = bursting pressure of shell, lbs. per square inch.

Then $p = \frac{2tT}{d}$

πdLs = shearing resistance of weld

$\frac{\pi d^2 p}{4}$ = pressure on head

so that $L = \frac{1}{2}\frac{T}{S}t$

for equal shearing and bursting strength.

If T be taken as 50000, and S as 40000

$L = \frac{5}{8}t$

So that $L = 1\frac{1}{2}t$, which the Committee has recommended above is safe.

Also, as no formula applies beyond the elastic limit, there is no need of crimping, whose effect, if any, can begin only after distortion begins.

Of course there is no objection to it, but the Committee could not recommend that it be required.

As heads convex to the pressure are much thicker than the shell, the welder is at some disadvantage unless the head be reduced in thickness as shown in Figure 1a. So the Committee recommends the form shown. Concave heads under certain conditions have the same objection, which can be met as in Figure

1b, which should be used where the difference between the sheets is 1-16 inch or more. Attention is called to the wording "not more than 45° in Figure U-3 at the lower right hand corner. This wording permits of any angle less than 45°, and if less angle be used, bad work will result.

The Committee recommends that "45°" be used, or better still, that the total Vee angle be used and described as "90°", this being the usual description. This is as shown in the first sketch in Fig. U-3. There is no distinction made in the distance, 1/16 in. between the edges of the Vee for light and heavy plate, and the amount shown is too great for 3-16 inch sheet. Otherwise the exact distance is of no importance, because any distance that will keep the sheets from lapping is enough, even .01 inch, and it is not possible to keep a uniform distance all along a seam. The Committee recommends that the wording, "the sheets must not be allowed to lap during welding," be used, say in Section U-102, at the end, and that the 1-16 inch dimension be omitted from the sketch. In making a double Vee weld in plate ¼ inch thick or less, it is not necessary to bevel the edges, as the metal can readily be fused half way through from each side. Also in 3-16 inch material, it is only necessary to bevel the head, this being enough for a good weld to be made. The Committee therefore recommends the following, to be added at the end of Section U-102.

"In material ¼ inch or less in thickness, the longitudinal seams need not be beveled," and the following, at the end of Section U-105. "In material less than ¼ inch thick, beveling the heads will be sufficient, and the shell need not be beveled at the head seams. One side of each girth seam shall be beveled."

The amount of reinforcement on a weld is of some importance, as the usual weld is weaker per square inch of section than the plate. Of course welds can be made with special wires that are stronger, but, as most of the wires used are not special, it is wise to use their properties in designing.

It has been found with such wires in practice that the amount of reinforcement necessary always to break low tensile strength plate varies from 25 to 50% of the plate thickness in a double Vee weld. In girth seams, which can safely be made of the single Vee type, the stress is very low and the amount of reinforcement need not be so great.

The Committee recommends the following as a rewording of the first sentence of Section U-102.

"All longitudinal seams shall be of the 90° double Vee type. Girth and head seams may be of the 90° single Vee type. Double Vee seams shall be reinforced to a total thickness of at least 1½ times the plate thickness, and single Vee welds to an amount equal to not more than 20% of the plate thickness."

The requirements for nozzle and nipple attachment are in some cases burdensome and unnecessary. The Committee realizes that reasonable difference of opinion may here exist, but would call attention to some of the designs in the code which it feels should be modified.

Section U-107 requires the use of a forged or rolled steel nozzle for all pipe connections over 3 inches in diameter. There is no objection to the construction except that for small tanks and large connections too much of the shell will be cut away for safety, and that its expense is very great. Some of the members of the Committee even feel that is is not as good as other constructions, because there is no reinforcement of the metal around the hole in the shell. It seems that for an 8 inch connection it would not be possible to make the hole in the shell less than 13 inches in diameter while with the construction shown in Figure 1c the hole would not be over 9½ inches before welding. This latter method of applying nozzles can be applied to any size or type of flange, and as it is readily shown that its factor of safety is very high—2 to 3 times greater than that of a riveted flange, which is permitted by the Boiler Code, and as it will reinforce the opening, the Committee recommends its use for any size pipe that is permissible.

Such a design may be varied to suit different conditions. One variation was used in the heads of tank No. 20, see Figure 5 in the Bureau of Standards report. The principle involved is to weld both inside and outside, even if projections are used inside to prevent the nipple or nozzle from blowing out. It is the same principle as of a double Vee weld, and should be applied in every case possible, the Committee believes, because of the increased rigidity and reinforcement of the shell obtained by its use.

The Committee unanimously objects to the 45° Vee shown in Figure U-3 in the shell around pipe nipples. Its effect is clearly shown in the head welds of the C tanks, which have about this angle but which are easier to get at than the same angle around pipe nipples.

The reason is that for good fusion the torch flame or electric arc must be perpendicular to the face of the Vee, and this cannot be done in the construction shown. Its solid appearance on paper gives a false sense of security, but it is almost, if not entirely impossible to make a weld "thoroughly from the bottom of the V'd shell plate" as called for in paragraph U-108 of the Code.

The Committee believes that by omitting the counter sinking of the hole, thus making the angle 90 °, the ease of making a good weld is much increased, and the constructions shown in Figure 1, c, d, e, f and k are much preferred. Provided they are limited to proper fields, they are all safe. The judgment of the Committee as to their limits is as follows:

Style	Shell thickness	Allowable pressure	Shell dia.	Pipe size
c	any	any	any	12 in. max.
d	3/16 in. min.	any	16 in. min.	1 in. max.
d	¼ in. min.	any	30 in. min.	1½ in. max.
d	⅜ in. min.	any	48 in. min.	2½ in. max.
e	any	any	Any that can be welded inside	8 in. max.
f	any	250 lbs.	Any too small to weld inside	4 in. max.
h	any	any	Any that can be welded inside	8 in. max.
k	any	150 lbs.	any	2 in. max.

While the Committee is opposed to the 45° Vee around pipe nipples, yet where the nipple is shouldered inside the tank, there is no danger of its blowing out, and hence they do not recommend prohibiting the design. Where there is no inside shoulder, the Committee believes the design should not be permitted.

There is, however, with shells which are thicker than the pipe, the difficulty of bringing the shell and pipe to the fusing point at the same time, and the danger of burning the pipe away for the same reason. This can be overcome, and a better weld made close to the pipe, by countersinking on the reverse side as shown in Figure 1h.

The beveling can be done with a cutting torch from either inside or outside, and the welding on the inside is easily done, and makes a very strong job. Everything considered, the Committee believes this is the best construction submitted, where it can be used. A further advantage is that it provides a perfect drain, which is not the case with some of the other designs.

It is not possible to put in the form of diagrams all possible good constructions, and the Committee feels that many others will be submitted to the Code Committee for approval, from time to time, which are equally as good as those shown, which are only typical.

The Committee recommends the use of extra heavy pipe for all nipples welded into shells.

The Committee has noticed considerable variation in the size of fillets, and an endeavor has been made to provide a standard that will be safe under all conditions. It is given in Figure 1g.

COMMENTS ON THE HYDROSTATIC HAMMER TEST

The conclusions of the Bureau of Standards as to the value of this test are as follows:

4. A hammer test cannot be relied upon to show more than a very few exceptionally defective welds.

5. The hammer test, as applied, apparently did not weaken the tank.
6. Hydrostatic pressure 1½ times the working pressure showed only a small number of imperfect welds, even when the hammer was used.

The Committee agrees entirely with these conclusions; but it is felt that, in view of the importance of the matter, some further statements are desirable.

A search has been made by one of the Committee, but only a few references have been found, and they are merely references to the fact that it is used.

The A. S. T. M. provides in its specification (**) for cast iron pipe as follows:

SECTION 14.

"The straight pipes shall be subjected to a proof by hydrostatic pressure, and if required by the engineer, they shall also be subjected to a hammer test under this pressure." (No details of how the test is to be applied are given).

"The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

Class	*Working Pressure	Test Pressure 20 in. Dia. & Larger	Less than 20 in.	†Fiber Stress at Test Pressure	†Fiber Stress at Test Pressure
				4 in.—1420	20 in.—2230
A	43 lbs.	150 lbs.	300 lbs.	18 in.—4200	60 in.—3230
B	86 lbs.	200 lbs.	300 lbs.		
C	130 lbs.	250 lbs.	300 lbs.		
				4 in.—1150	20 in.—2900
D	173 lbs.	300 lbs.	300 lbs.	18 in.—2760	60 in.—3780

*Added to Table.

†Calculated from data in specifications.

It will be seen that the ratio of test pressure to working pressure varies widely—from about 7.0 to 1.7, and that the fiber stresses in the table, which are also shown in Figure 2, are likewise irregular, and variable. The Committee is not in a position to criticize, and simply points out the variations as indicative of either unusual conditions or of lack of standardization, probably the latter.

The data and wording of the American Water Works Association specifications are identical with those of the A. S. T. M.

Statements are given on page 34 of methods of hammer testing cast iron and steel pipe.

From both of them it will be seen that the hammer used is not heavy, and from a study of the tables of test pressures, the fiber stresses used are not as high as in the Bureau of Standards tests. The test pressures in the proposed revision of the A. S. M. E.

**Page 343 of the 1921 issue of the A. S. T. M. Standards.

Rules for Piping and Fittings*, are the same as those of the A. S. T. M.† and no hammer test is specified in either case.

The fiber stresses due to these pressures are irregular; for example:

Dia.	Welded	Test Pressure	Fiber Stress
1½ in.	lap	1000	5500
1½ in.	butt	700	3880
3 in.	lap	1000	7600
3 in.	butt	800	6080
12 in.	lap	800	12800

(See Figure 3).

It seems clear from the above, that the hydrostatic hammer test is, 1st, not standardized,

2nd, not believed by the users to be of value, except occasionally.

It should be noted that all the fiber stresses quoted above, with one exception, are less than that used in the Bureau of Standards tests, 12,000 lbs. Of course the higher the fiber stress, the greater the chance to detect imperfections, but, as only two of the Bureau of Standards tanks failed at or below this 12,000 lbs., it seems a fair inference that the Code test is not capable of detecting defects that are known to exist, and which no one would willingly allow to go into service.

This inference is based on the results of the Bureau of Standards tests, in which tanks known to have "bad" welds were not found by the Code test, even when a 12 lb. sledge was used with enough force to dent the shell of the tank. (Tanks X8 and X12).

It may help, in discussing the test, to state the experience with it and to see, if possible, what it might be legitimately expected to accomplish.

One of the members of the Boiler Code Committee, who is a strong advocate of the Code test, states that in his experience it has been of much value in detecting leaks and other imperfections.

One of the members of the present Committee, who has used the test for several years, states that the use of the hammer has found some leaks that were not shown up by the pressure alone, and he would not want to omit its use.

It has been the experience of one job welding shop, in the case of many hundreds of cast iron vessels, ranging in size from small auto cylinders to very large heating boiler sections, that, with a city water pressure of from 40 to 60 pounds, an ordinary machinist's hammer, used in proportion to the weight of the vessel, will invariably detect a strain due to uneven shrinkage, and that if no effect is produced by the hammering, there is also invariably

*Published in Power, Oct. 31, 1922.

†Loc. Cit. page 220.

successful service. It has also been their practice for over five years, in cases where the working pressure is known, to use the Code test on all welded cast iron pressure vessels, such as steam jacketed kettles, and they state that they would not feel safe in

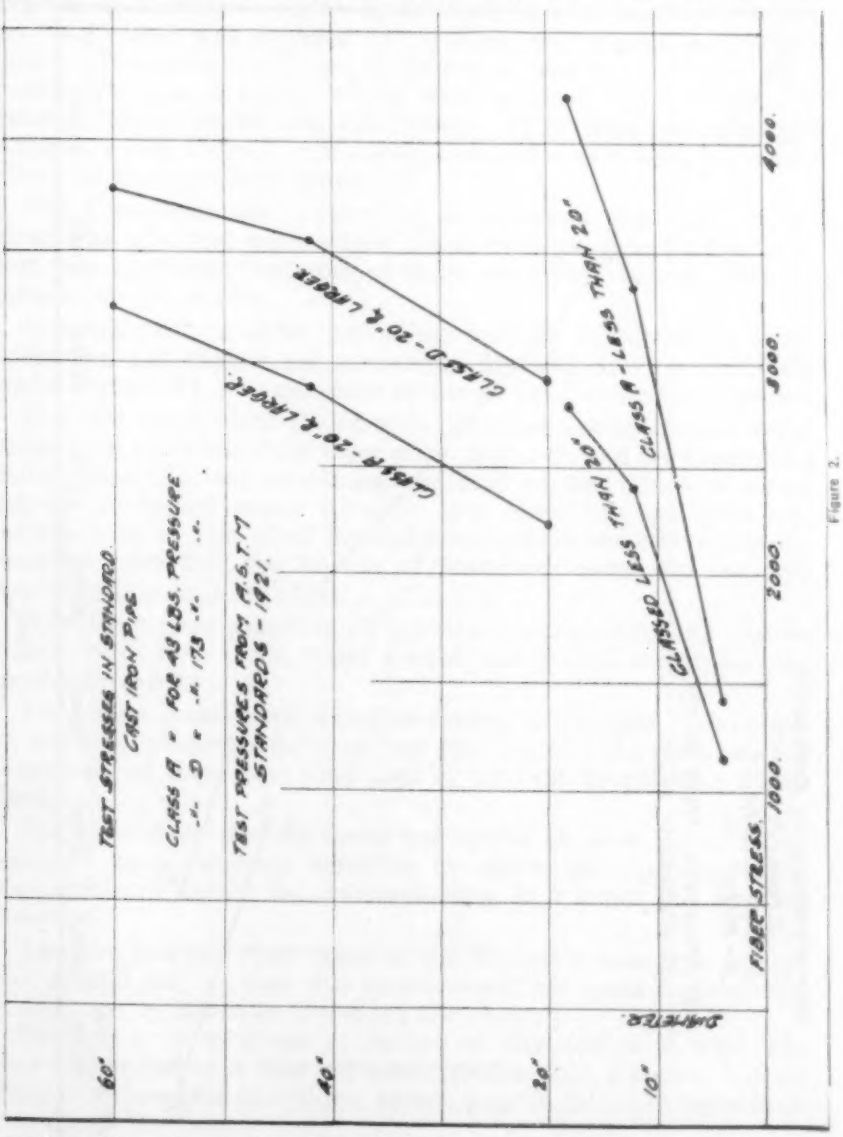


Figure 2.

letting them leave the shop without being so tested, and that no vessel of this type passing this test has ever failed in service.

It is their belief that the test is specially adapted to detect strains, which are serious in cast iron welds, and that it will not,

from their experience, detect an imperfect cast iron weld unless there is a strain in it, because the factor of safety in the vessels referred to is made very high because of foundry conditions, so that even an imperfect weld will be plenty strong enough.

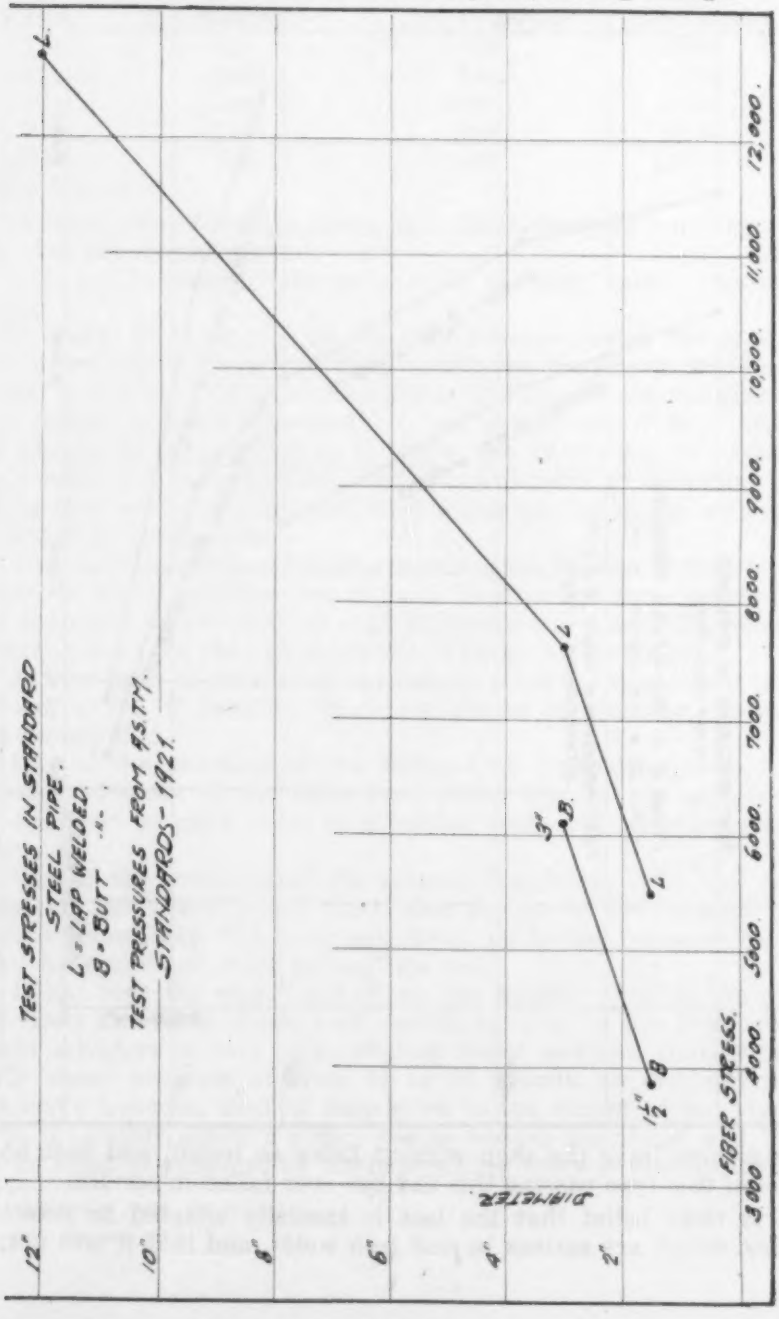


Figure 3.

The statement usually made, as far as the Committee knows, is that the Code test should detect a bad weld. At once the question may be asked, what is a bad weld? The Committee knows of no attempt to evaluate or define it. There are evidently various degrees of badness in welds, as in anything else, but in the tests, no "bad" weld was detected by the Code test except one, (Tank X15). The other one found by it was a good weld, (Tank K4), containing a local strain, which was repaired, and the tank on retest broke at 50,500 lbs. fiber stress. It is quite probable that Tank X15 had a strain in the weld, due to the thin weld having to stand all the shrinkage stress.

The Committee has inquired of its members and others as to their idea of a bad weld, which would be discovered by the Code test, and has found that none of those questioned had any definite opinion on the matter.

It seems quite probable that no one had any definite ideas or information and that is not surprising, as these are the first tests made that would give any data as far as the Committee is aware.

It would appear that the stresses produced are of a much lower order than those resulting from water hammer, and the Committee thinks that the two have been confused in the minds of some. All the foregoing seems to show that there has not been any definite idea of just what the hydrostatic hammer test would accomplish, and that the Bureau of Standards tests give the only available data as to its effect.

It does not seem possible that the strain produced by any reasonable force of blow could detect a weld that is 50% sound, and the tests bear this out.

Very much more work would be needed to evaluate it completely, but the Committee believes that the result of the tests and the experience of those who have used it, warrant its adoption in the Code.

The tests show that 12 tanks out of the 48 were either found leaky or more seriously defective by either the Code test or a fiber stress of 24,000 lbs., corresponding to 3 times the working pressure.

Also the average yield point of the materials used was enough over 24,000 lbs., so that this stress would not cause deformation in any case, as has been discussed elsewhere.

The lowest fiber stress at failure of any double V weld was over 44,000 lbs, so it does not seem possible that a double V weld could be injured by 24,000 lbs. stress, and, in fact, the tests show that this is the case.

The Committee therefore recommends, that, after the Code test has been applied, the hydrostatic pressure be increased to 3 times the working pressure, and held there for 3 minutes, and that if a pressure vessel pass these tests, it be accepted.

Method of Testing Cast Iron Pipe.

In actual practice the pipe is hammered during cleaning. In this work the sand is first cut from the pipe by scrapers and after this is done, a man walks down the length of pipe pounding it with a one pound hammer having a sixteen inch handle. As he returns to the scraper he also pounds the pipe.

After cleaning, the pipe is subjected to a hydrostatic pressure as specified and is again hammered. A medium blow is used for all this work. Apparently, the only advantage of the hammer test is that it sometimes opens up cracks that otherwise may not have shown leakage.

Method of Testing Steel Pipe.

Sometimes the hydrostatic pressure may be held only by a film of oxide scale on the inside of the pipe or along the weld in which case a slight vibration from the blow of a hammer will start failure. As a vibration of this kind carries some distance from the blow even when the pipe is full of water it is not necessary to take any chances of injuring the metal by too severe a blow. Hand hammers and used, 2 pounds in weight in the case of boiler tubes, trip hammers arranged so as to hit the pipe every 5 feet and pneumatic hammers to strike the center of the pipe and start a vibration throughout the length, no one type having been standardized. In case of the large hammer weld pipe, an 8 pound hammer with a 3 foot handle is used, and for important work the pressure is maintained 3 or 4 minutes while blows are struck along the weld. Care must be taken to protect the eyes of the operator in case failure should occur.

COMMENTS ON TANK X15

This tank was a "bad" welded one, and after the rupture, the weld was found to be only about 5/32 inch thick.

This thickness of weld in ⅜ inch plate is not enough to force the cooling contraction stresses into the plate, as would be the case if the weld were heavy enough. Therefore this weld was doubtless under a heavy strain, and while it stood a static load of 375 lbs., 1½ times the working pressure, it would not stand shock at 300 lbs. The same effect is shown in the tensile shock tests in test pieces SW9 to 16, "poor" and "bad" welds, in which the static load at 12000 lbs. fibre stress was sustained, but which gave way under shock, in 6 cases out of 8 at 12000 lbs. fiber stress, and in the other two at fiber stresses of 13600 and 14600, an average increase of 17% over 12000.

In this case, as in tank K-4, the condition of local stress seems to govern. Such local stresses must of necessity be very high, and it seems that the Code test detects them readily.

Conclusions:

The Code test detects local stresses, and so should be used in all cases.

REMARKS MADE BY H. W. HEINRICH OF THE TRAVELERS INSURANCE COMPANY, AT THE WELDING CONFERENCE FEBRUARY 14-15, 1923.

The tests which have recently been conducted and completed at the Bureau of Standards have in our opinion justified in a great measure the claim made by the Welding Fraternity. These tests have also justified and confirmed the conclusions already drawn by the Travelers from a review of the experience of welded unfired pressure vessels now in service, this experience representing over 10,000,000 tank years. The Travelers is, of necessity, conservative and we have been very slow and very reluctant to join in any movement urging the inclusion in the A. S. M. E. Pressure Vessel Code of requirements which would permit fusion welding. We have felt the need for just such facts as are now available through the series of tests conducted at Washington, D. C. But for our own purposes, for insurance purposes, we have felt that such additional proof was not a necessity. It is our practice to support and to be governed by Federal, State and Municipal laws where effective, but these laws in many cases do not apply to unfired pressure vessels whereas insurance is universally applicable.

We are now insuring and have insured in 1922, pressure vessels of many kinds and at varying pressures, having fusion welded longitudinal as well as girth and head seams. We are satisfied now and we were satisfied before these recent tests were made that fusion welding could be made insurable. Our experience has been satisfactory and we expect to continue to insure welded vessels with equally good results.

Fusion welding is an art which, in our opinion, has come to stay and we believe that we can best serve the interests of the public and assist to a greater degree in the safe development of welding practice by working with the welders, with the manufacturers, and with the various engineering societies authorized to establish rules and regulations as far as we can consistently do so.

When fixing the safe working pressures for insurance purposes of fusion welded unfired pressure vessels, we have, pending more definite methods of determining the ratio of the value of the weld to the value of the solid plate, been assuming arbitrarily a joint efficiency of 50%. We further reserve the right, as does any Insurance Company, to accept or reject any or all tanks before or after inspection. The point I wish to bring out here is that merely because a tank is fusion welded, it is in our opinion not considered uninsurable.

As a result of the data now available as submitted by the Bureau of Standards, I see no reason why a good longitudinal weld, and by this I mean a double V weld, is not equivalent in strength to the average triple riveted butt strap joint and it should be allowed an equivalent efficiency or approximately 85%. In making this statement I have reference to tanks which are constructed in accordance with the A. S. M. E. requirements, provided these requiremnts are amended as was suggested at this meeting to permit only double V welded longitudinal joints.

In the determination of the insurability of welded vessels we place even greater reliance upon methods of construction than upon tests made after construction, such as hydrostatic and hammer tests. At the same time there is no question but that the hydrostatic and hammer test will reveal some defective welds and we believe that the test now prescribed by the Pressure Vessel Code should be retained. A hydrostatic pressure test of 1½ times the safe working pressure should be applied and the vessel should be hammer tested while under this pressure. The hydrostatic pressure should then be raised to at least twice the safe working pressure but not to the yield point of the metal. The term "safe working pressure" should in my opinion have but one definition, this being based on A. S. M. E. Code *Construction* and not on operating pressures carried on the vessel in service.

COMMENTS ON PHYSICAL QUALITIES OF MATERIALS

The Code has no specifications for pipe, which was used for 9 of the regular tanks. Two of these, B1 and B2, were of wrought iron, which is naturally weak longitudinally in the tank or transversely in the skelp. The committee feels that for this reason wrought iron pipe is not a suitable material for pressure vessels, unless the factor of safety be very high, and that lap welded steel pipe could be used instead without any hardship.

All of the other materials came within the following limits:

Tensile Strength Max.	63000
Tensile Strength Min.	47500
Yield Point Max.	55250
Yield Point Min.	28600
% Elong. in 8 inches	35.3 Max.
% Elong. in 8 inches	10.0 Min.

It seems fair to omit the pipe tanks, and the special tanks made of 10 gage material, because the Code does not take account of either. If this be done, the figures become:

Tensile Strength Max.	60200
Tensile Strength Min.	47500
Yield Point Max.	46000
Yield Point Min.	28600
% Elong. in 8 inches	35.3 Max.
% Elong. in 8 inches	13.8 Min.

In all cases the yield point was at least $\frac{T.S.}{2}$

Of the regular tanks made of welded plate, the C were the only ones that did not meet the following requirements:

$$\text{Tensile Strength} = 55000 \text{ Max.}$$
$$\text{Yield Point} = \frac{T.S.}{2} \text{ Min.}$$
$$\% \text{ Elong. in 8 inches} = \frac{1.500.000}{T.S.}$$

or the Code requirements.

$$\text{Tensile Strength} = 55000 \text{ Max.}$$
$$\text{Yield Point} = 24000 \text{ Min.}$$
$$\% \text{ Elong. in 8 inches} = \frac{1.500.000}{T.S.}$$

They had too high a tensile strength and too low an elongation for both. The evident cause of the high tensile strength is the high carbon content, .24% as a minimum. The cause of the low elongation is not evident.

The average tensile strength of the regular tank plates, excluding the C tanks, and including X-13, 14 and 15, which were of the same thickness, was 49200, the maximum in the 16 plates being 52900, and the minimum being 47500.

The Committee members questioned said that there had been no trouble in getting plates of this strength, so that the Committee feels that the Code specification for tensile strength is quite liberal.

The argument in favor of low tensile strength plate for welding may be stated as follows:

With a given welding wire, a given weld strength may be obtained, and no more. So that if the plate be stronger than the weld, the efficiency of the joint is less than unity, though its value cannot be known.

With a weld stronger than the plate, the joint efficiency is more than unity, and while its value cannot be known, it is immaterial.

Now ordinary low carbon steel welding wire will give a weld of about 52000 lbs. per square inch of plate section, when not reinforced, and reinforcing will run it up to about 58000 lbs. Allowing for unavoidable defects in welds, 55000 lbs. is about as high tensile strength as should be used, if a 100% weld is desired. In fact, the Committee would rather see a lower limit. But as the Bureau of Standards tests show such close approximation to 100% welds, when properly made, and as the specification plate will not average 55000 lbs., it is doubtless safe to use that figure as the maximum limit.

It should be noted that the double V welded regular tanks welded with ordinary low carbon steel welding wires, gave efficiencies ranging from 90 to 115%, while the "good" welds in the special tanks in all cases had over 100%.

Again, there is nothing to be gained by using a high strength plate with a low strength weld. In this case the efficiency of the weld is less than unity, and the strength of the weld governs, instead the strength of the plate, as in the previous case. In other words, a 100% weld in a 50000 lb. plate is just as good as a 50% weld in 100,000 lb. plate, and requires no more material.

Of the special tanks, those 3/16 inch thick failed to meet the above requirements in all 8 cases, the elongation being too low. This low elongation was attended by a high yield point, due largely to cold rolling, shown by the microscope, and to the 8 inch gage length.

The A. S. T. M. specification for Boiler and Firebox Steel, require the elongation of material ¼ inch thick or less to be measured on a gage length of 24 times the thickness, or in this case 4½ inches, which would probably increase the amounts found to suit the specification, because of the following.

Returning to the 10 gage (.14 inch thick), material, the average tensile strength of all test pieces from the Bureau of Standards tests was 60425, and the average elongation in 8 inches, 11.7%. A test made at the Union Carbide and Carbon Research Laboratories on some pieces of the original material left over from the same tanks, but on a 4 inch gage length, gave an average tensile strength in 8 pieces, of 61000 lbs. and an elongation of 18.4%, an increase over that from the 8 inch gage length of 57%. The 3/16 inch material would act in the same general way, as it is well known that an increase in gage length decreases the percentage of elongation.

The elongation of the ¼ inch material, as might be expected, comes much closer to the above two specifications, in three cases out of eight meeting them, and if it had been measured on the gage length called for by the Boiler Code, 6 inches, it doubtless would have done so in all cases. It is therefore evident that some allowance must be made for thin material, and it seems from the tests, that the A. S. T. M. specifications do not allow quite enough in some cases. This allowance should take account of the unavoidable cold rolling of thin sheets, which raises the yield point and tensile strength and lowers the elongation.

As the yield point is raised by cold work more than the tensile strength, it seems perfectly safe to allow a high yield point especially since the material is annealed by the welding for quite some distance from the weld, as is shown by the location of the ruptures in the "good" special tanks, which have broken, of course, in their weakest part. This annealing increases the elongation, allowing the sheet to absorb the welding strains, in spite of higher tensile strength that the Code allows. From the foregoing, it is safe to provide that material ¼ inch thick or less shall have a

Tensile strength 60,000 Max.
Yield point $\frac{T.S.}{2}$ Min.

$$\% \text{ elong. in 8 inches } \frac{1{,}500{,}000}{T.S.}$$

provided that the elongation be measured on a gage length of 24 times the thickness and that the Code Chemical analysis be complied with, and the Committee so recommends. The Committee believes that the use of a definite minimum for the yield point is not as good as the limit used in the Boiler Code, in which

$$\text{Yield point} = \frac{T.S.}{2} - \text{Minimum}$$

because the former excludes Armco iron, a very good material, while the latter admits it. Whatever form of specification is used, Armco iron should be allowed. Further, the Committee believes that if its recommendation as to hydrostatic test at three times the working pressure be adopted, the yield point minimum of 24000 lbs. is too low, as it is just three times the fiber stress, 8000 lbs. of which the Committee is in favor.

As it is seen from tables II and III that the Code specifications for tensile test are met by all material that approaches the chemical requirements, the Committee recommends that these specifications, modified as to the form for yield point be adopted, as follows:

Tensile strength, 55000 lbs. per square inch minimum

$$\text{Yield point } \frac{T.S.}{2} \text{ minimum.}$$

$$\% \text{ elongation in 8 inch, } \frac{1{,}500{,}000}{T.S.} \text{ minimum.}$$

For material ¼ inch or less in thickness, the elongation shall be measured on a gage length of 24 times the nominal thickness. For material less than ¼ inch thick, the tensile strength may be increased by 600 lbs. per square inch for each .01 inch of such decrease in thickness. (The Code does not allow the use of material less than 3/16 inch thick. The above provision would permit the use of 58750 lbs. steel for 3/16 inch thickness. The maximum of the tanks at the Bureau of Standards was 56650).

COMMENTS ON CHEMICAL REQUIREMENTS OF PLATE

The chemical analysis of the regular and special tanks show that the Code requirements are met in all cases, except in the B, and C tanks. B-1 and B-2 are evidently wrought iron and B-3 is possibly Bessemer Steel, neither of which is provided for in the Code.

The C tanks are much too high in carbon to meet the Code, but as they failed at rather low stresses by head weld failure, and as these welds were quite imperfect, it is not possible to say anything about their longitudinal seam strength compared with the plate.

The Committee would point out the following:

1st, None of the members has had any unusual difficulty in getting material to meet the Code requirements.

2nd, They believe that low carbon is one of the essential features of plate for safest welding, because

A The lower the carbon, the less injury is done to the steel by any method of heating, or by hot or cold working.

B The lower the carbon, the less the tensile strength, and low tensile strength allows the welding strains to be absorbed by the plate, rather than concentrated in the weld.

C On the other hand, there comes a time when the lowering of the carbon may mean too much extra cost for the benefit derived, and the tests show good results with the steels used, which had a maximum carbon content of .15%, including both the regular and special tanks.

The Committee therefore feels that the Code specification for carbon is all right and should be retained, especially as it checks nicely with the physical properties recommended.

The amounts of the other elements as given in the Code are such as would be found in any good steel, and their adoption is recommended. However, it would be well, if possible, to have all the specifications for steel for fusion welding the same. It does not look consistent to have slight variations in the different Codes. (See Code for Class C. vessels, and the Heating Boiler Code).

The Committee recommends the following as a specification that will fit all cases:

Carbon, .15% max.
Manganese, .30% to .60%
Phosphorus, .04% max.
Sulphur, .05% max.

It is not believed that it is necessary to say anything about chromium, nickel or silicon content, but that high grade steel is necessary, and that it should be required to be of good welding quality. If these two requirements are met, the Committee believes no trouble will exist. They have no evidence that the welds in the tanks were in any way defective because of the chemical composition, and the members advise that there was no difficulty experienced in welding any of it.

It is believed that there should be a low limit on the manganese, to insure good steel, and .30% is recommended. This would exclude Armco Iron, which is entirely suitable for pressure vessels, provided its low tensile strength, (about 45,000 lbs.) is allowed for, and its use should be permitted by some such wording as

"The use of ingot iron is permitted provided a fiber stress of 7200 lbs. per square inch at the working pressure is not exceeded."

The analysis of the steels of the regular tanks were made by the American Rolling Mill Company at their laboratories, and those of the special tanks at the Union Carbide & Carbon Laboratories. In the latter case only the carbon and manganese were determined, as all the steel was of firebox quality, and it was believed would

not carry undue amounts of the other elements.

Tank	C	Mn.
1	.12	.28
2	.11	.31
3	.13	.31
4	.12	.30
5	.11	.30
6	.11	.31
7	.13	.29
8	.12	.31
9	.14	.30
10	.12	.31
11	.13	.31
12	.11	.31
13	.11	.37
14	.12	.34
15	.09	.33
16	.14	.31
17	.10	.31
18	.15	.31
19	.15	.38
20	.10	.28
21	.11	.31
22	.12	.30
23	.12	.31

COMMENTS ON WELDING WIRE

The analyses of the welding wires may be divided into two general classes, gas and electric, all of which were low in phosphorus and sulphur. Of the former, there were nine, one of them being Armco, one nickel steel, and one a special rod of high manganese and silicon content, the other elements being normal. With these exceptions, they were all of one type, a low carbon steel, the maximum carbon being .067%, and the maximum manganese, .132%. The carbon in the nickel steel wire lies in the range of the Society of Automotive Engineers specification 2330, in which the carbon range is from .25 to .35%, .30% being desired.

Of the latter, two of the seven were Armco. The rest were of the usual type of bare wire, and had maximum of .147% carbon and .651% manganese. There is nothing in the test to indicate that differences in the wires had anything to do with the results, and it is evident that any one of them will give ample strength in

a double V weld made in low tensile strength plate, and properly reinforced.

The Committee feels, however, that it is not necessary to put in the Code any specifications for wires, and that a statement that the wire should flow freely and smoothly, and without detrimental action, would be enough, because chemical composition alone is not a guarantee of good quality.

Beside this, users of welding wire are very particular to get wire that works well, and the welder notices at once any poor wire, and complains about it.

Also, the manufacture of welding wire is in the hands of a few companies, who have their reputation at stake, and who are very careful.

The Committee recommends that all detail specifications of welding wire be omitted, but that the general qualities of good wire, (flowing smoothly and freely, and without detrimental action during welding), be inserted..

TESTS OF WELDED SPECIMENS IN TENSILE TESTING MACHINE, THE TEST PIECES BEING STRUCK WITH A HAMMER WHILE UNDER LOAD

These tests were made at the suggestion of Prof. H. L. Whittemore, to see if the shock from a blow would have any effect on a welded test piece under load, and were designed to simulate the pressure vessel test in the Code. It has been known for a long time that welded test pieces properly designed and made would stand severe bending by blows without rupture, but as far as is known, this is the first time that shock tests under tensile load have been made. They were carried out at the Union Carbide & Carbon Research Laboratories.

The test pieces were made of the steels left over from the X and K tanks, and were welded in the same ways as were the tanks, see Fig. 5 and Bureau of Standards Fig. 2. The welding wire used was all straight low carbon steel, the same as was used on the X tanks.

The test pieces were machined on the edges to the dimensions shown in Figure 5, so that they were duplicates of the welded test pieces from the K and X tanks.

There was no difficulty in calculating what the tensile load should be to correspond to the various tank test pressures, and these were determined for each test piece, using the individual sectional areas. But as these did not vary seriously, an average value was taken for each thickness.

7000 lbs. for $\frac{3}{8}$ in. x $1\frac{1}{2}$ in. nominal size.
4500 lbs. for $\frac{1}{4}$ in. x $1\frac{1}{2}$ in. nominal size.
1700 lbs. for 3-16 in. x $\frac{3}{4}$ in. nominal size.

These are the loads corresponding to a tank fibre stress of 12000 lbs., or to a tank pressure of $1\frac{1}{2}$ times the working pressure.

At the approximate load given above, each test piece was given three blows on the weld from a pendulum hammer, the rigging being shown in Fig. 4. If failure did not occur, the load was increased to the next amount, see Table 1. After remaining under the load for one minute, the test piece was again struck 3 blows.

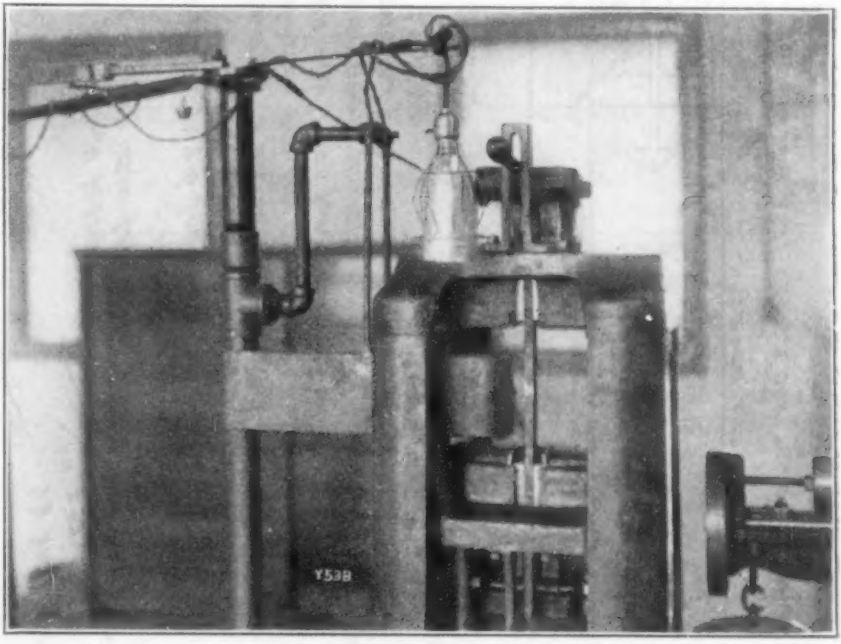
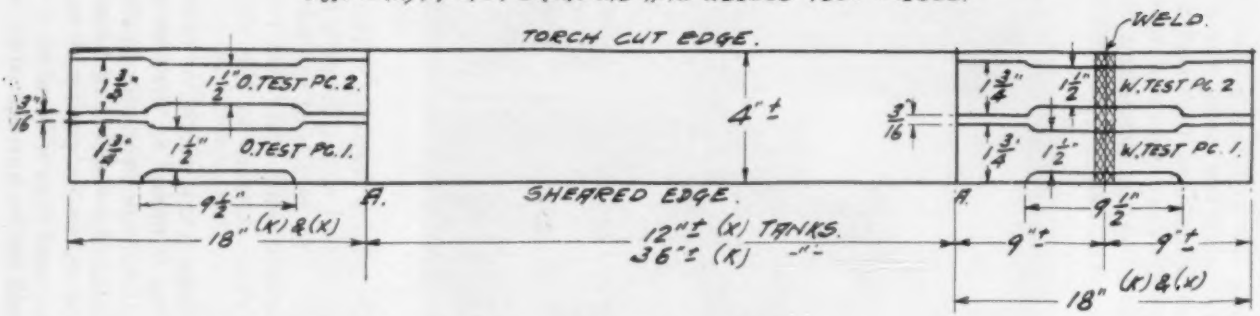


Figure 4.

In this way the test was continued till failure occurred. The test piece was examined after each load increment and after each blow, to see if any defects could be observed. The results of the test are given in Table 2, in which are also entered some other test results for comparison. Table 3 gives the fiber stresses in the various tests assembled for easy comparison.

It was not found possible to determine what weight of hammer should be used so that the shock of the hammer on the test piece would be proportionately the same as the shock on the tanks during the tank tests. It was therefore felt that the weights of hammers for the different thicknesses could be made proportional to the moments of inertia of the test pieces, and that a blow of 1 foot pound on the 3-16 inch test pieces would not be unreasonable, when

its size was considered. However, it was found that the weight of this hammer was greater than expected, and the blow was nearer



MAKE FROM STRIPS CUT FROM TANK SHEETS.

MARKS.
O. = ORIGINAL SHEET. W = WELDED PIECE.
K. = (K) TANKS.
X. = (X) -"-
FIRST NUMBER = TANK SERIAL NO.
SECOND -"- . = TEST PC. -"- -"-.

THUS,—
X.12 02 = 2ND ORIGINAL TEST PIECE FROM TANK X12.
K.1 W1 = 1ST WELDED TEST PIECE FROM TANK K1.

PREPARE AND WELD TEST PC's IN SAME WAY AS LONGITUDINAL SEAMS OF TANKS FROM WHICH STRIPS COME, ARE PREPARED AND WELDED. DO NOT USE CUTTING TORCH EXCEPT TO CUT OFF AT A & A. WELD ENTIRE 4" BEFORE CUTTING OUT TEST PIECES.
MACHINE OUT O & W TEST PIECES, AND STAMP AS SHOWN.
MARK LEFT OVER CENTER PIECES WITH TANK GAGE LENGTH 8".

Figure 5.

to 1½ ft. lbs. The blow for the ¼ inch test pieces was about 5 ft. lbs. and for the ⅜ inch ones, about 16 ft. lbs.

It was also felt that though these blows were probably more severe than those called for in the Code, it would do no harm to see their effect, and so they were used.

The following points were noted during the tests:

1. None of the "good" welds failed in the weld.

2. None of the ⅜ inch "fair" welds failed in the weld. All of the ¼ inch and 3-16 inch "fair" welds broke in the weld.

3. All of the "poor" and "bad" welds failed in the weld.

4. The fiber stresses at which these test pieces failed, and the fiber stresses at which the corresponding tanks failed, are not wide-

TABLE 1.

TENSILE LOADS ON TEST PIECES IN TENSILE SHOCK TESTS.

Nominal Thickness			Fiber stresses corresponding to loads
⅜ in.	¼ in.	3/16 in.	
7000	4500	1700	12000
7460	4800	1820	12800
9330	6000	2270	16000
11190	7200	2720	19200
13060	8400	3180	20400
14920	9600	3640	25600
16790	10800	4080	28800
18660	12000	4540	32000
22380	14400	5440	38400
26120	16800	6360	40800
29840	19200	7280	51200
33580	21600	8160	57600

ly different, when all conditions are considered. This is particularly true in the case of the "good" welds, as shown by Table 2.

5. The shock effect was probably greater in the test pieces than in the tanks. It was noticed that the blows many times gave a permanent bend to the test piece, and in all cases the pieces sprung under the blows from 1-32 inch to 1-16 inch, which could be clearly seen by the eye.

6. There was a noticeable difference in the sounds of different test pieces. "Good" welds below the yield point, and other welds before cracks developed, (and such a crack is really the yield point of the welded piece), gave a clear ringing tone, compared with a duller, sluggish note at or beyond the yield point. No conclusions are to be drawn from this, but it is mentioned as a matter of record.

7. The tensile test results of the unwelded plate are about the

TABLE NO. 2.

Results of tensile shock tests on welded pieces made with welds like those on K and X tanks.

Test piece	Quality	Nominal thickness	Nominal width	Like tank	First load lbs.	Hammer blow ft.-lbs.	First bending at lbs.	Yield point lbs.	Sound of blows changed lbs.	Broke lbs.	Broke lbs. per square inch.	Fiber Stress at which like tank ruptured	REMARKS
SW 1	good	3/8 in.	1½ in.	K1	7000	16	9330	16790	18660	29650	49600	51200	Broke outside weld—no defects in or near weld.
SW 2	"	"	"	"	"	"	——	18660	——	29840	50000	"	"
SW 3	"	"	"	"	"	"	——	18660	——	31100	53800	"	"
SW 4	"	"	"	"	"	"	——	16790	——	29350	51500	"	"
SW 5	fair	"	"	X13	"	"	7000	18660	18660	29840	50200	37440	Badly bent at 11190. Broke outside weld. No defects in or near weld.
SW 6	"	"	"	"	"	"	——	18660	——	29600	50400	"	"
SW 7	"	"	"	"	"	"	——	16790	——	29350	50000	"	"
SW 8	"	"	"	"	"	"	——	18660	——	31290	53400	"	At 26120 crack ⅛ inch long in center of one edge with no further defects.
SW 9	poor	"	"	X14	"	"	——	——	——	7000	12000	16000	7000 static no effect. 1st blow at 7000 opened crack half thru, and broke before load could be picked up. Half welded.
SW10	"	"	"	"	"	"	——	——	——	7000	12000	16000	"
SW11	"	"	"	"	"	"	——	——	——	8650	14600	"	Before loading small crack visible along V. It opened a little at 7000, and the blows opened it more at 7460 further opening. 40 per cent welded.
SW12	"	"	"	"	"	"	——	——	——	7000	12000	16000	No defects at 7000 static. Blows opened up along V, and broke before picking up load.
SW13	bad	"	"	X15	"	"	——	——	——	7000	12000	8000	Small crack along V before loading. 1st blow opened it 2-3 thru. Would not pick up load again. 1-3 welded
SW14	"	"	"	"	"	"	——	——	——	7000	12000	8000	No cracks visible at 7000. Blows opened up V 60 per cent thru. Would not pick up load again. 1-3 welded.
SW15	"	"	"	"	"	"	——	——	——	7000	12000	8000	Cracks along V before loading opened slightly when loaded. Blows opened up 60 per cent thru. Would not pick up load. 1-3 welded.

SW16	"	"	"	"	"	"	——	——	——	7460	13600	8000	Cracked half thru at 7000 under blows. Broke at 7460 before blows. 40 per cent welded.
SW17	good	1/4 in.	"	X9	4500	5	——	14400	——	20200	53000	60100	Broke outside weld. No defects in or near it.
SW18	"	"	"	"	"	"	7200	13700	——	20000	51200	60100	Broke outside weld. Small crack at 16800. No other defects in or near weld.
SW19	fair	"	"	X10	"	"	——	12800	12000	16075	43200	44480	About 40 per cent not welded in center at 13400 small cracks showed up on each edge at center, which were a little enlarged by blows.
SW20	"	"	"	"	"	"	——	12000	——	13825	36400	44480	25 per cent welded.
SW21	poor	"	"	X11	"	"	——	——	——	9250	25800	28800	At 4500 no effect from blows. At 4800 V opened, and increased up to 8400.
SW22	"	"	"	"	"	"	——	——	——	9600	27300	28800	Cracked when struck at 4500, and increased from that up to 9600.
SW23	bad	"	"	X12	"	"	——	——	——	7200	18700	28800	At 4800 under blows, V opened a trifle and increased to 7200.
SW24	"	"	"	"	"	"	——	13450	12000	16750	43400	28800	At 7200 small V opened upon one edge, and increased up to 14400.
SW25	good	3-16 in.	3/4 in.	X16	1700	1 1/2	——	——	——	6730	51200	57500	Broke outside weld. No defects in or near it.
SW26	"	"	"	"	"	"	——	5440	——	7260	49400	"	"
SW27	"	"	"	X17	"	"	——	5440	——	6690	48800	"	"
SW28	fair	"	"	"	"	"	——	5440	——	5760	40000	47900	Cracks in weld, broke on loading. Large spot center of weld not fused.
SW29	"	"	"	X18	"	"	——	——	4540	6870	47000	47900	Crack visible at 2270, opened up more up to 6870. Spot of oxide at crack.
SW30	"	"	"	"	"	"	——	5440	——	7850	——	47900	Broke outside weld. No defects in or near weld.
SW31	poor	"	"	X19	"	"	——	——	——	5590	39100	24360	At 2270 crack appeared along V increased to 5440.
SW32	"	"	"	"	"	"	——	——	——	7160	49100	24360	Crack opened up at 5440.
SW33	"	"	"	"	"	"	——	——	——	6975	47600	24360	Cracked slightly at bottom of V at 3180, and increased to 6360. 60 per cent fused.
SW34	bad	"	"	"	"	"	——	——	——	4655	31100	24360	40 per cent welded. Crack not visible up to break.
SW35	"	"	"	"	"	"	——	——	——	6820	45400	24360	Crack started at bottom of V load increased to 5440, and got larger up to 6360.

TABLE 3.

FIBER STRESSES AT FAILURE OF WELDED TEST PIECES, UNWELDED PLATE, AND CORRESPONDING TANKS.

Quality and nominal thickness	Test Pieces	Tanks	Fiber Stress at Failure: Test pcs.	Tanks	Plate
Good ⅜ in.	SW 1	G 1	49600	44800	49900
	2	G 2	50000	53200	49800
	3	G 3	53800	44800	59900
	4	H 3	51500	57600	49900
		H 1		51200	52300
		Average	51200	50300	52400
Fair ⅜ in.	SW 5	C 1	50200	37400	60200
	6	C 2	50400	33600	59800
	7	C 3	50000	43600	59600
	8	F 1	53400	36000	49100
		F 2		44250	48900
		F 3		29250	48900
		H 1		50500	49200
		H 2		42200	48700
		X 13		37400	48350
		Average	50800	39300	52640
Poor ⅜ in.	SW 9	X 14	12000	16000	50350
	10		12000		
	11		14600		
	12		12000		
		Average	12650	16000	50350
Bad ⅜ in.	SW 13	X 15	12000	9600	47500
	14		12000		
	15		12000		
	16		13600		
		Average	12400	9600	47500
Good ¼ in.	SW 17	X 9	53000	60000	52400
	18	X 20	51200	52800	50100
		Average	52100	56400	51250
Fair ¼ in.	SW 19	X 10	43200	44500	52700
	20	X 21	36400	50000	52100
		Average	39800	47250	52400
Poor ¼ in.	SW 21	X 11	25800	28800	52850
	22	22	27300	32700	50200
		Average	26500	30250	51820

TABLE 3 (Continued)

Quality and nominal thickness	Test Pieces	Tanks	Fiber Stress at Failure Test pcs.	Tanks	Plate
Bad ¼ in.	SW 23	X 12	18700	28800	47750
	24	23	43400	20800	48400
		Average	31050	24800	48075
Good 3/16 in.	SW 25	X 5	51200	44200	50700
	26	X 16	49400	56500	54950
	27		48800		
		Average	49800	50350	52825
Fair 3/16 in.	SW 28	X 6	40000	47200	51500
	29	17	47000	46800	55400
	30		39100		
		Average	42030	47000	53450
Poor 3/16 in.	SW 31	X 7	49100	37000	56650
	32	18	31100	23800	53500
	33		47600		
		Average	42600	30400	55000
Bad 3/16 in.	SW 34	X 8	31100	18500	54400
	35	19	45400	24700	53750
		Average	38250	21600	54075

same as those of the "good" welded test pieces, as shown by Table 2.

Conclusions.

A. Tests of the type carried out seem to be as consistent with the results of the tank test as could be expected, and mutually confirmatory.

B. Welds of reasonable quality are not injured by severe shock under heavy tensile stress. It seems fair to draw this conclusion because these pieces show the same strength as the straight tensile tests of unwelded pieces, within commercial limits. See Table 3.

C. The double V weld is stronger than the single V.

FLATTENING TESTS OF WELDED PIECES

This test was suggested by Mr. H. W. Heinrich, Engineer of the Travelers Insurance Company, and is intended to simulate the action under internal pressure of a badly shaped tank, as for in-

stance one which had not been properly rolled before welding, or which had been distorted during welding. The Union Carbide

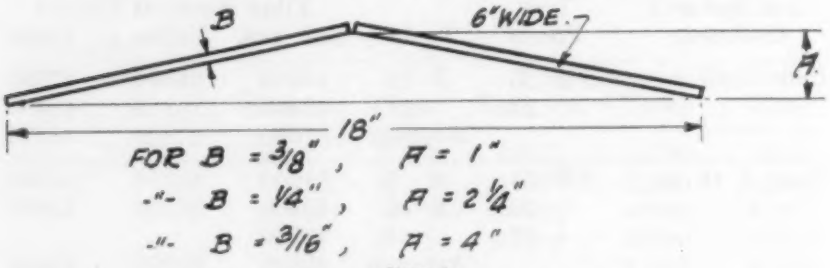


Figure 6.

and Carbon Research Laboratories agreed to make the tests.

The test pieces were all 6 inches wide, of three nominal thicknesses 3/8 inch, 1/4 inch, and 3-16 inch, and were welded in the same way as the tanks were welded, that is, with "good", "fair", "poor," and "bad" welds, as shown in Bureau of Standards, Fig. 2.

As there was no tank material left, other materials were used, the tensile strengths of which were:

3/8 inch—50300 lbs. per square inch.
1/4 inch—64000 lbs. per square inch.
3/16 inch—61200 lbs. per square inch.

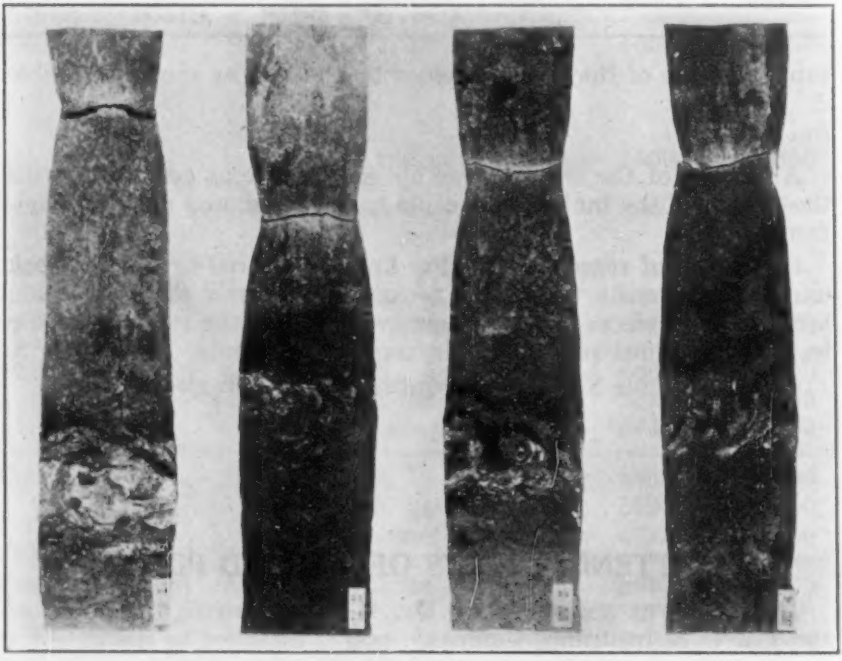


Figure 7.

TABLE 4.

RESULTS OF FLATTENING TESTS OF WELDED PLATES

Test pieces, Quality and thickness	Height at start	Height Straight	Lbs. load to bring straight	Lbs. load to keep straight	Height at max. load	Total Amount bent	Height at 1st crack	Load at 1st crack	REMARKS
B 1 good ⅜ in.	3.06 in.	2.12 in.	2160	2400	1.88 in.	1.18 in.	—	—	No weld defects. Bend all outside weld.
B 2 fair ⅜ in.	2.88 in.	2.03 in.	1930	2020	1.79 in.	1.09 in.	—	—	No weld defects. Bend all outside weld.
B 3 poor ⅜ in.	2.91 in.	1.89 in.	940	—	—	—	2.7	940	At 940 lbs. and 2.7 in. cracked. When flat, cracked half through weld.
B 4 bad ⅜ in.	2.9 in.	1.88 in.	1140	—	—	—	2.44	1140	At 1140 lbs. and 2.44 in. cracked. When flat, cracked half through weld.
B 5 good ¼ in.	4.57 in.	2.56 in.	1200	1225	2.38 in.	2.19 in.	—	—	No weld defects. All bend in plate.
B 6 fair ¼ in.	4.63 in.	2.56 in.	1180	1200	2.35 in.	2.28 in.	—	—	No weld defects. Most of bend in plate.
B 7 poor ¼ in.	4.50 in.	2.37 in.	600	—	—	—	4.00	600	At 600 lbs. and 4 in. load fell off. When flat, cracked about half through weld.
B 8 bad ¼ in.	3.52 in.	1.66 in.	400	—	—	—	2.60	400	At 400 lbs. and 2.6 in. cracked one edge When flat, broken almost entirely through weld.
B 9 good 3/16 in.	6.42 in.	2.05 in.	540	540	2.05 in.	4.37 in.	—	—	Load dropped at 469 lbs. and 5.8 in. This was yield point. Bend all in plate. No weld defects.
B 10 fair 3/16 in.	6.37 in.	2.05 in.	645	645	2.05 in.	4.31 in.	—	—	Yield point at 645 lbs. and 5.30 in. Bend all in plate. No weld defects.
B 11 poor 3/16 in.	6.36 in.	2.34 in.	550	—	—	—	5.30	550	Yield point at 550 lbs. and 5.30 in., and cracks half through. Broke 60 per cent through weld when flat.
B 12 bad 3/16 in.	6.53 in.	2.38 in.	315	—	—	—	6.00	315	At 315 lbs. and 6 in. cracks on both edges. When flat, broke 2-3 through weld.

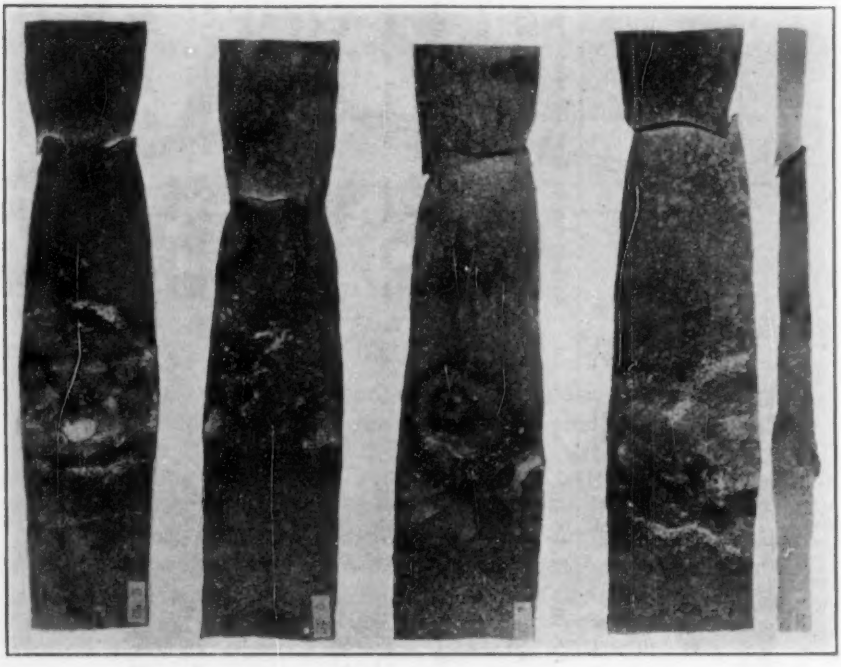


Figure 8.

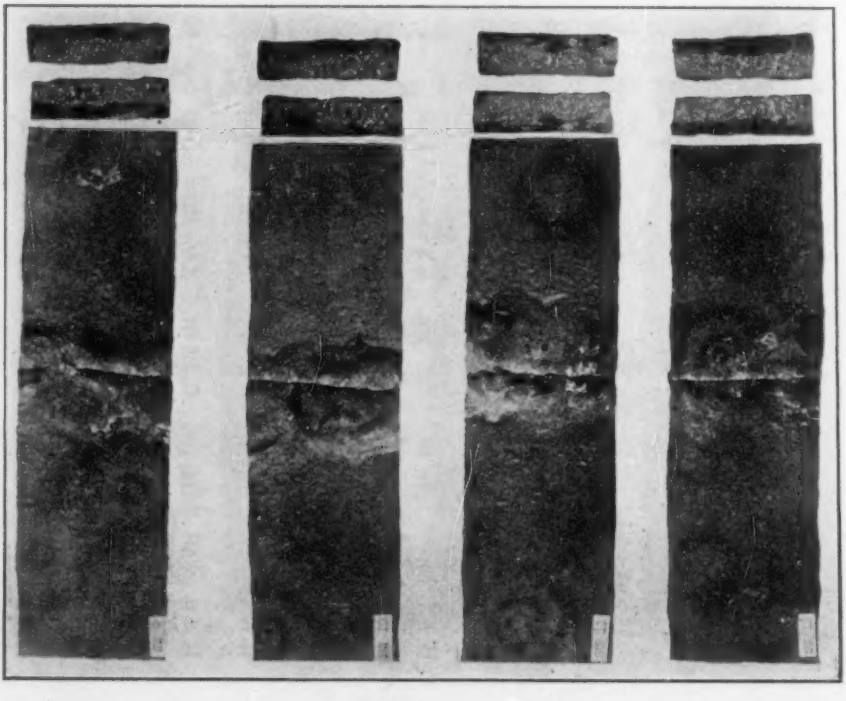


Figure 9.

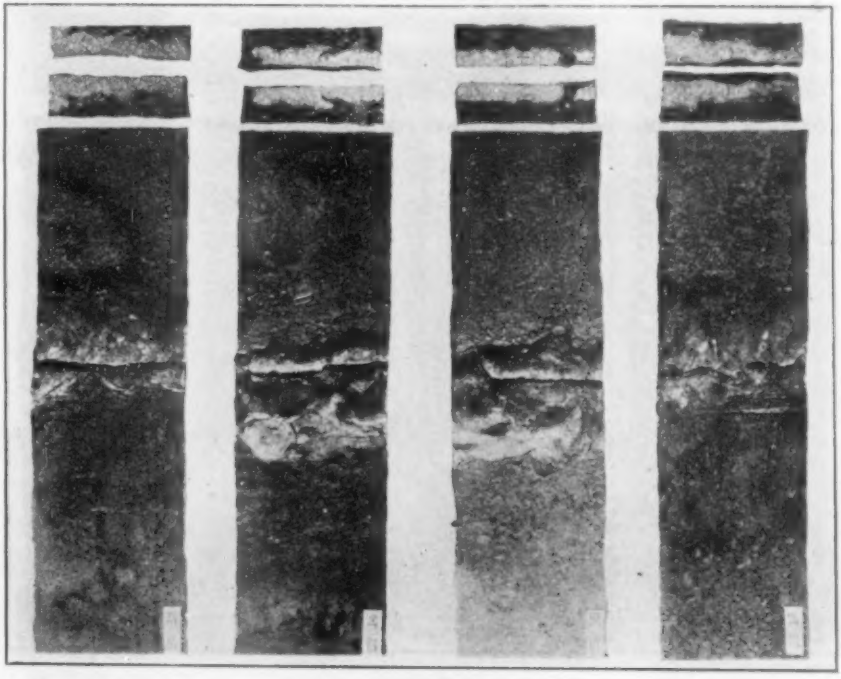


Figure 10.

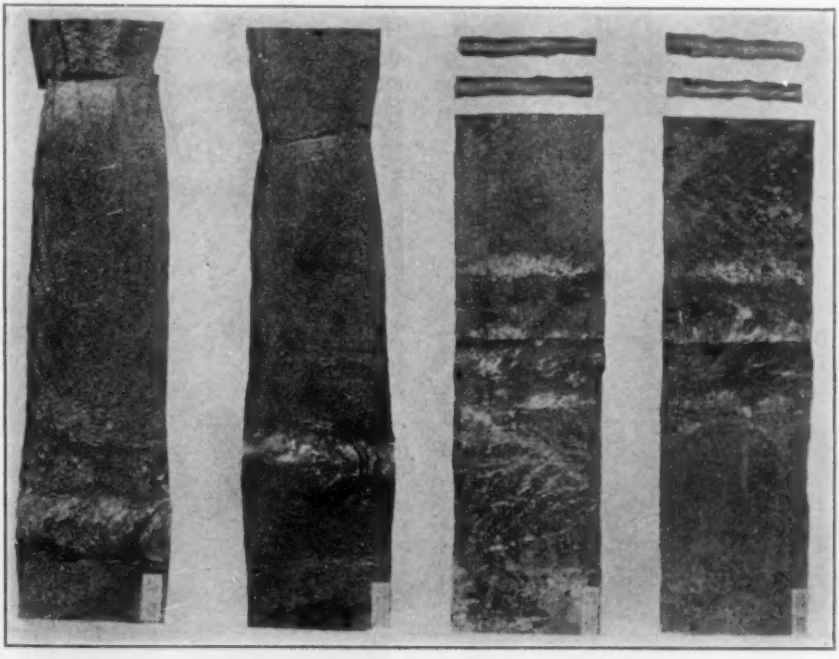


Figure 11.

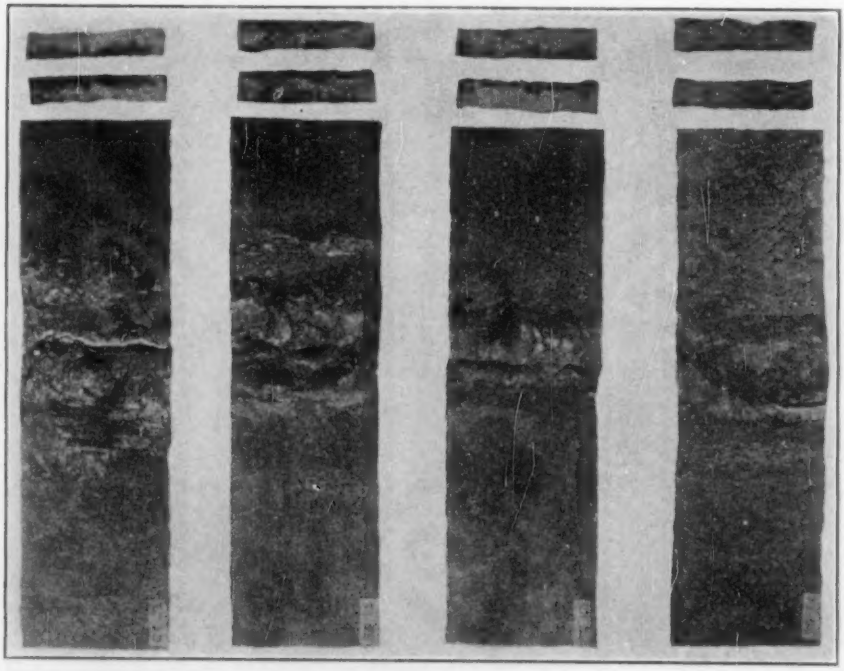


Figure 12.

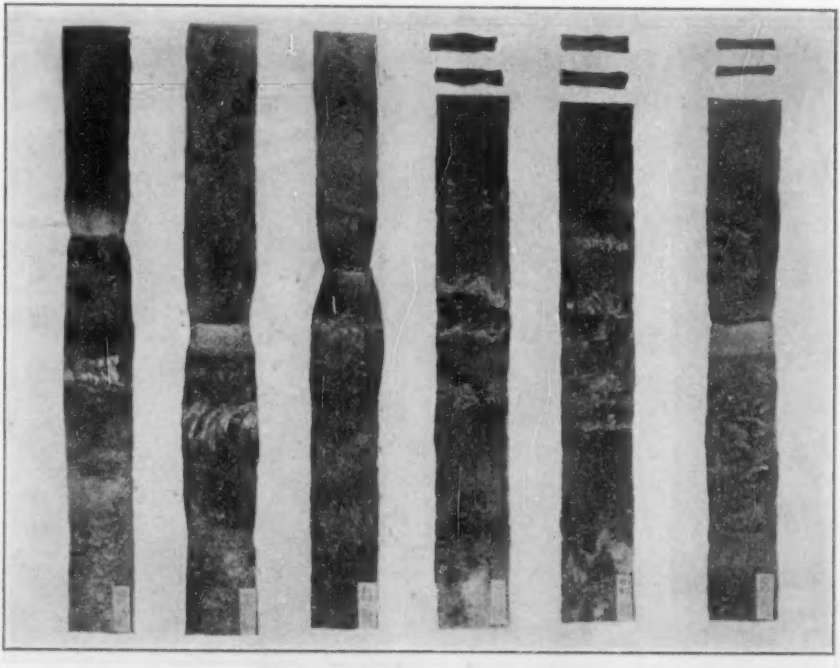


Figure 13.

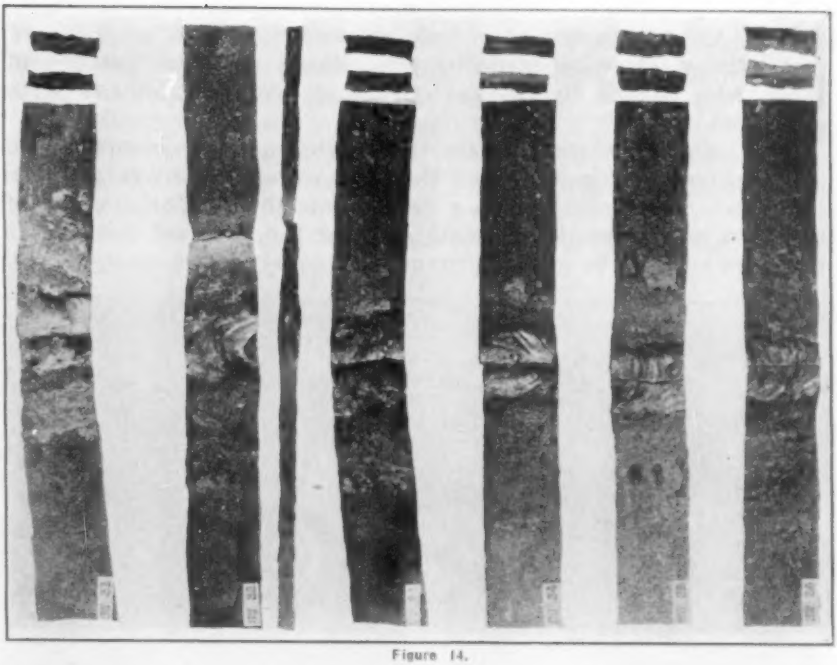


Figure 14.

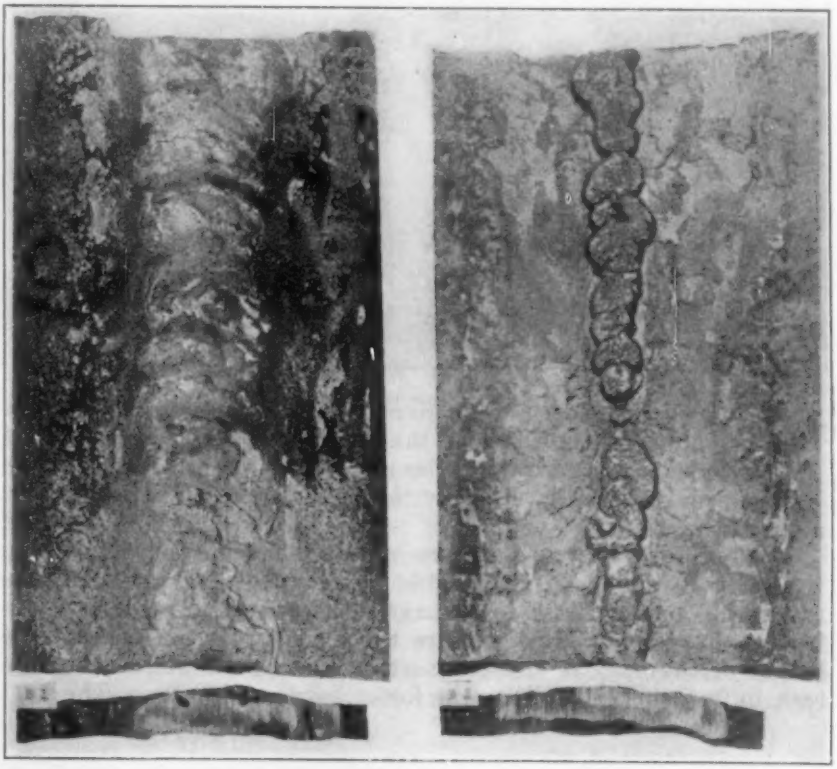


Figure 15.

Ordinary low carbon steel welding wire was used.

All the welds were made by one welder, who was not one of those who welded the tanks. Ordinary welding methods were employed.

The test pieces were welded so as to leave the halves at an angle, shown in Figure 6, and the tests were made by forcing the bent test pieces straight in a testing machine. The amount of the bend was selected arbitrarily, but for the different thicknesses they are such as to give approximately equal fibre stresses. Also

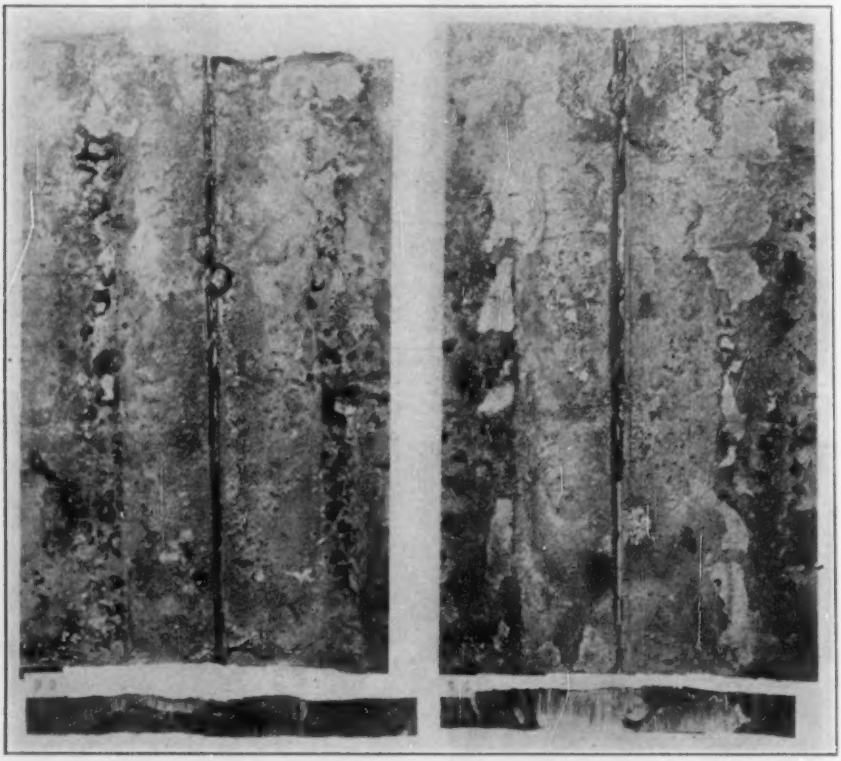


Figure 16.

these amounts are much more than would be allowed in a rolled shell by good shop practice. The results of the tests are given in Table 4, and Figs. 7 to 20 show the appearance of the test pieces after straightening.

The test pieces as welded were laid on blocks under each end on the platen of the testing machine to allow for the spring of the test piece, and blocking so arranged between them and the lower head as to fairly well distribute the load across the piece. The height of the apex of the piece was taken before and during the test, by measuring between the lower head and platen. The load

required to hold straight while under load was, in the unbroken test pieces, less than that needed to make them straight after the load was released, and both were recorded.

The following points may be noted:

1. The "good" and "fair" test pieces gave no evidence of distress in the weld or its vicinity. The bending took place in the plate, where it had been annealed by the heat.

2. The "fair" welds were reinforced somewhat, which should

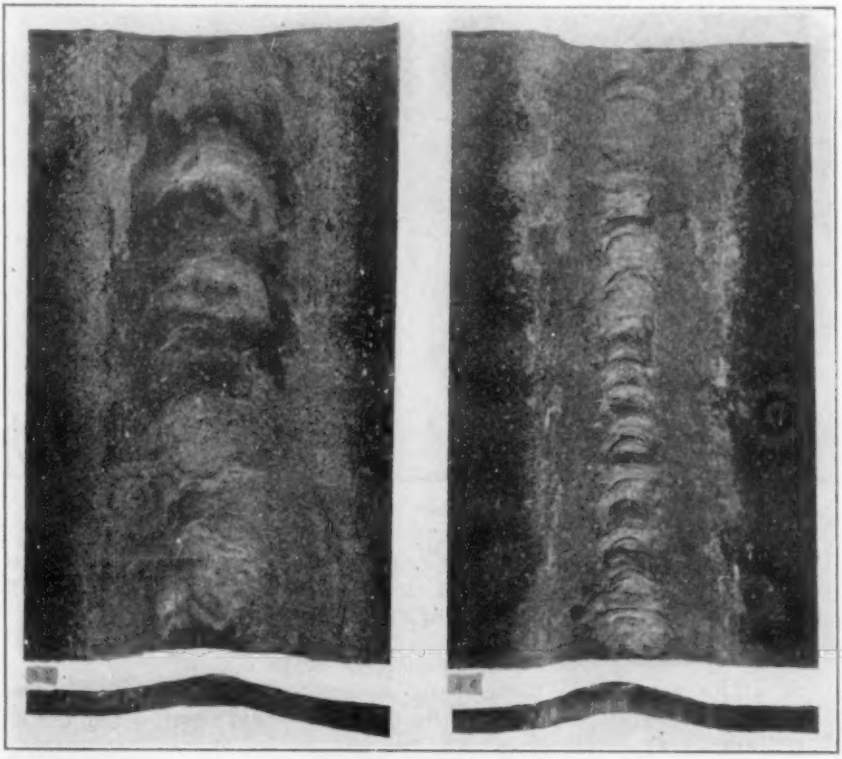


Figure 17.

not have been done. This partly accounts for their somewhat greater relative strength.

"Fair" test pieces should show up better in this bending test than in a tensile test, because a defect in or near the neutral axis has less effect under the former stress than under the latter.

3. The correspondence between these test results and the results of rerolling the ¼ in., 3/16 in. and 10 gage shells in the X series is complete. The maker of these tanks reported that all of these shells were rerolled; that no effect could be seen on the "good" and "fair" ones even by testing with kerosene, but that the "poor" and "bad" welded shells cracked in some cases. That no

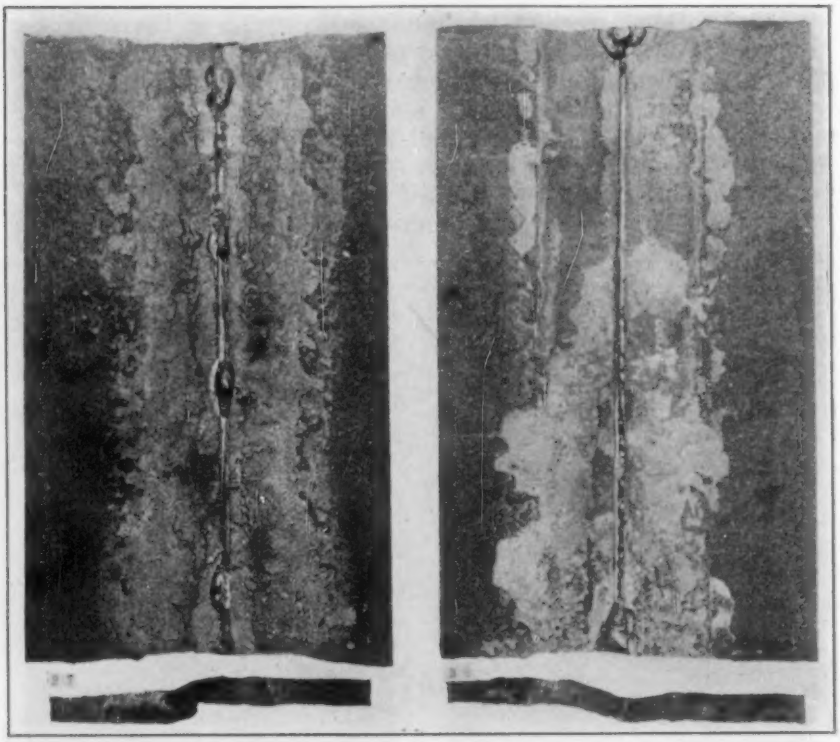


Figure 18.

damage was done to the "good" and "fair" ones is clear because of the high fibre stresses at which they broke, and because all of the "good" ones broke outside of the weld.

Conclusions.

A. The results of these tests are consistent with and confirmatory of the superiority of the double V weld in all other tests.

B. These tests check the results of practice in rerolling tank shells, in that in neither case was any apparent injury done to "good" welds by the treatment which they received.

COMMENTS ON PARAGRAPH U-101 ESPECIALLY ON MARKING AND STAMPING

While it is not within the province of the Committee to consider these matters, which are covered by 14 sections of the Boiler Code, yet they felt that it would do no harm to speak of the questions of marking and stamping. On the other matters in the four paragraphs referred to, they have no comments to make.

The Committee realizes that the Code Committee has the right to ensure the use of the proper methods and materials by any means they see fit, and which accord with their experience. It is felt, however, that such regulations as may be required should be put in the pressure vessel Code in full to avoid referring to the Boiler Code.

It might be possible to simplify the procedure in some of its details in cases where a large number of small tanks is the product. In such a case it is possible that 500 or more will be turned out in

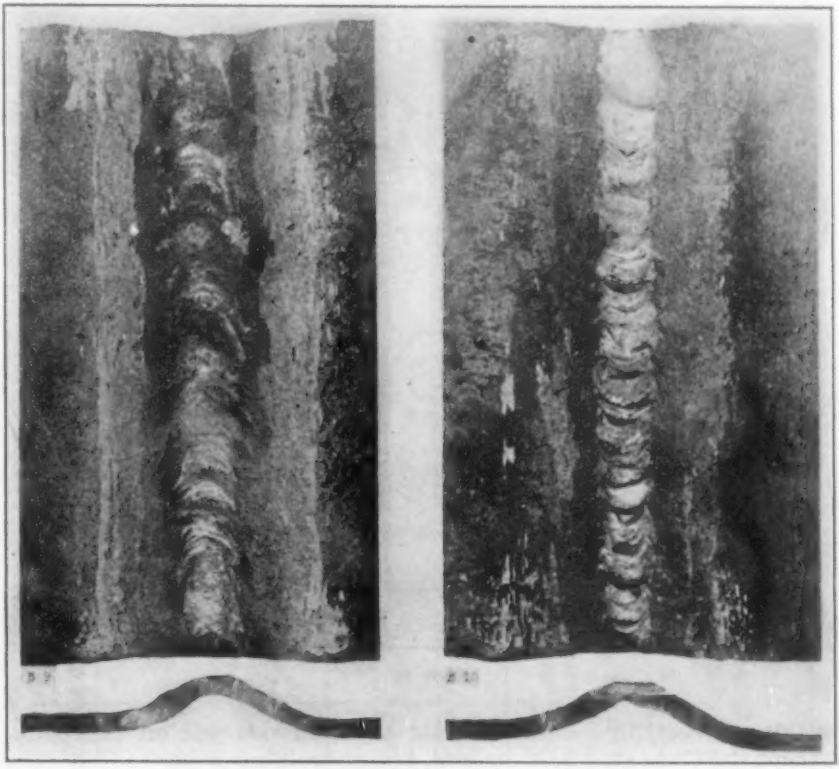


Figure 19.

one day, and the problem is difficult of solution. The marking of 1500 shell plates and heads in one day, and the signing of 500 certificates by the maker and also by the inspector may be pointed out as only some of the difficulties.

The following suggestions occur to the Committee:

1st, As many makers flange their tank heads, one mark in the center of each head would seem to be enough.

2nd, That only one mark near the edge of the shell sheet, would

seem to be necessary, as the sheets are ordered in large lots cut to size, except for trimming.

3rd, That a name plate, properly secured to the tank, might be a substitute for much of the stamping required by the Boiler Code. This could be welded to the shell or head (with bronze for ease and speed), before the tank is finished, or during welding of the head

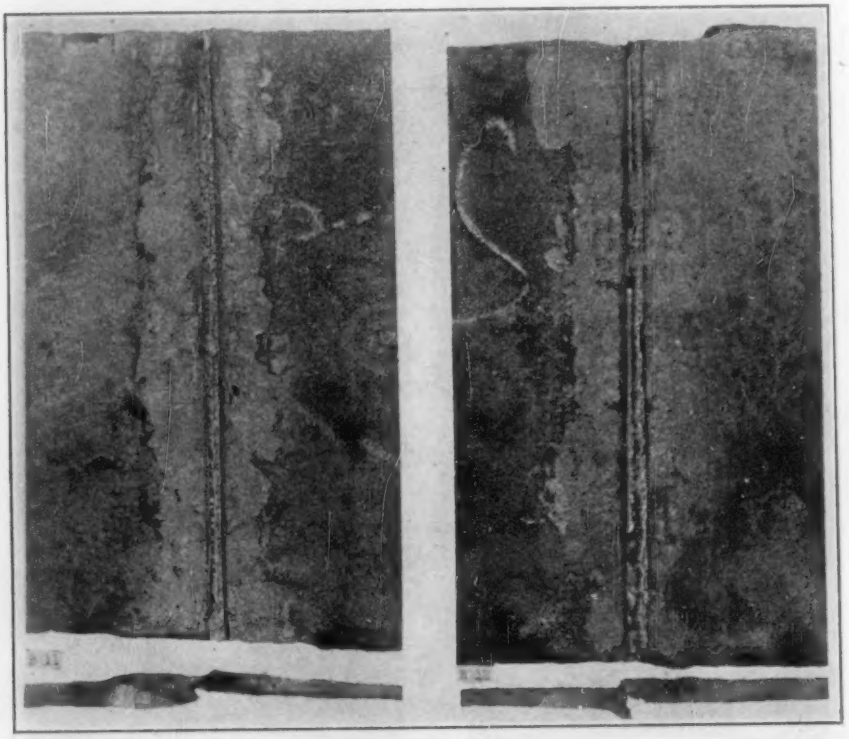


Figure 20.

seams. Everything could be cast or otherwise put on the plate except the Code stamp, if desired, before welding it on.

It would seem that the maker's report would be simpler than that for Code boilers. And it might be so arranged to cover as many tanks made from the same heat of steel as desired, to save signatures. As many copies of it as needed could be made.

Figure 21 is a rearrangement of Bureau of Standards figures 3 and 4, and shows the advantage of the double Vee weld. It includes all of the tanks tested.

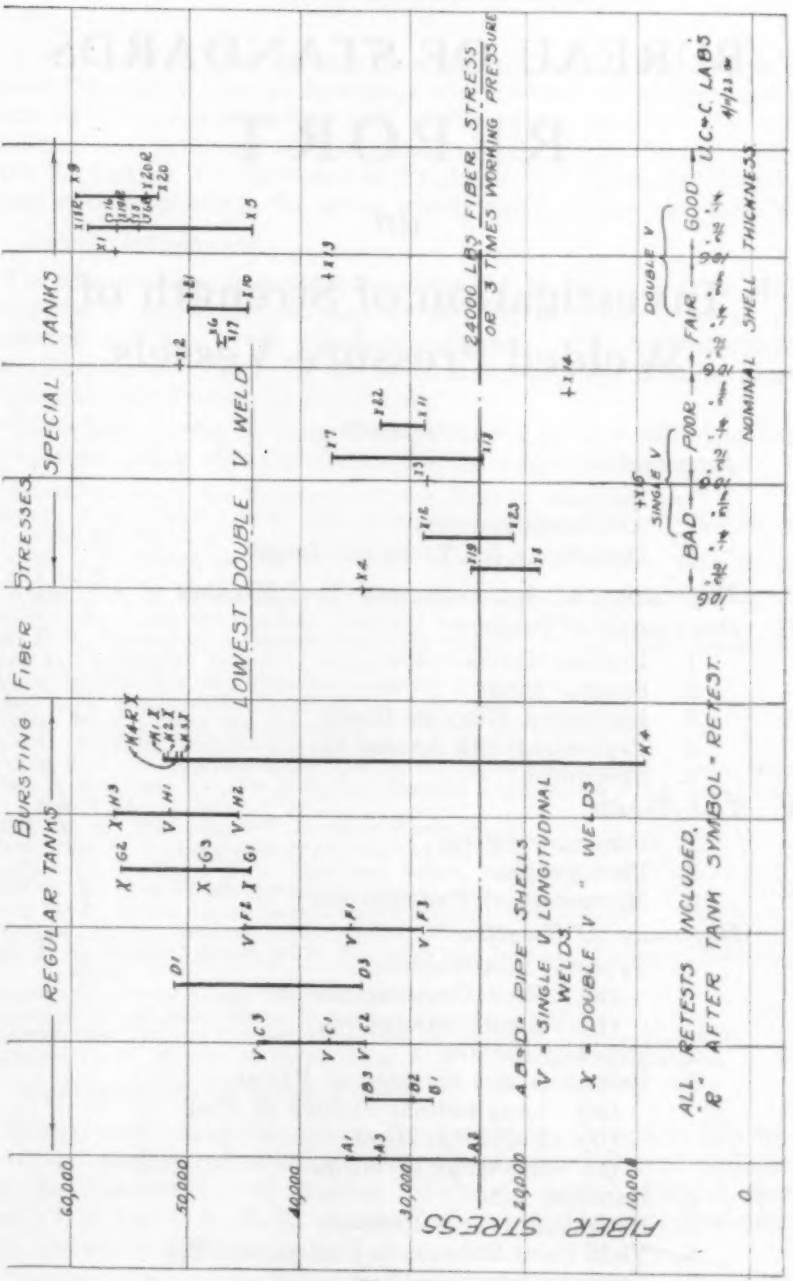

BURSTING FIBER STRESSES SPECIAL TANKS
REGULAR TANKS
LOWEST DOUBLE V WELD
24000 LBS FIBER STRESS OR 3 TIMES WORKING PRESSURE
FIBER STRESS
60,000
50,000
40,000
30,000
20,000
10,000
0
A B & D = PIPE SHELLS
V = SINGLE V LONGITUDINAL WELDS
X = DOUBLE V " WELDS
ALL RETESTS INCLUDED.
R AFTER TANK SYMBOL - RETEST.
SINGLE V
DOUBLE V
BAD
POOR
FAIR
GOOD
NOMINAL SHELL THICKNESS
U.C.C. LABS 4/1/23

Figure 21.

APPENDIX A

BUREAU OF STANDARDS

REPORT

on

Investigation of Strength of Welded Pressure Vessels

CONTENTS

I. *Introduction.*
- 1. Purpose
- 2. Acknowledgements
- 3. Definitions for Technical Terms

II. *Description of Apparatus and Test Methods*

III. *Description of Tanks.*
- 1. Regular Tanks
- 2. Special Tanks
- 3. Inspection Plugs in Heads
- 4. Preheating and Annealing
- 5. Specimens

IV. *Test Results.*
- 1. Summary Sheets
- 2. Photographs
- 3. Microscopical Examination

V. *Discussion of Results.*
- 1. Types of Construction
  - (a) Shell Construction
  - (b) Head Construction
- 2. Types of Failure
- 3. Pressures and Stresses at Failure
  - (a) Longitudinal Failure in Shell
  - (b) Failure in Head
  - (c) Efficiency of Welds
- 4. Hammer Test
- 5. Hydrostatic Test Pressure
- 6. Yield Point Stresses in Hydrostatic Test
- 7. Test of Inspection Plugs

VI. *Conclusions.*

I. INTRODUCTION

1. *Purpose.*

The purpose of this investigation as outlined by the Pressure Vessel Committee was to determine the strength of welded tanks made in commercial shops, and to determine whether the acceptance test proposed in the Code, (A. S. M. E. Boiler Code, Part 1, Section VI, Mechanical Engineering, November 1922), would reveal defects in the tanks which would make them unsafe.

2. *Acknowledgements.*

The chemical analyses were made by the American Rolling Mill Company through the courtesy of Mr. W. J. Beck, Director of Research and Mr. J. H. Nead, Metallurgist. The microscopical examinations were made by Mr. H. S. Rawdon of the Metallurgical Division of the Bureau of Standards.

The wide interest in these tests is shown by the following list of visitors, many of whom made helpful suggestions.

Carter, G. O., Linde Air Products Co., New York, N. Y.
Critchett, J. H., Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.
Dawson, J. R., Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.
de Windt, J. P. H., Steam Boiler & Fly-Wheel Service Bureau, New York, N. Y.
Doyle, E. A., Linde Air Products Company, New York, N. Y.
Fish, E. R., Boiler Code Committee, Chairman Unfired Pressure Vessel Committee.
Flinn, A. D., National Research Council, New York, N. Y.
Haffner, W. H., York Manufacturing Company, York, Pa.
Heinrich, H. W., Travelers Insurance Company, Hartford, Conn.
Kremer, W. R., Vilter Manufacturing Company, Milwaukee, Wis.
Lane, G. H., York Manufacturing Company, York, Pa.
McCabe, J. C., Commissioner Building & Safety Engineering, City of Detroit, Mich.
Miller, S. W., Union Carbide & Carbon Research Laboratories, Long Island City, New York.
Miller, W. B., The Pfaudler Company, Rochester, N. Y.
Moore, Prof. H. F., University of Illinois, Urbana, Ill.
Moulthrop, I. E., Boiler Code Committee, Boston, Mass.
Obert, C. W., Boiler Code Committee, Boston, Mass.
Poste, E. P., Elyria Enameled Products Company, Elyria, Ohio.
Redington, H. R., National Tube Company, New York, N. Y.
Reid, J. G., Hartford Steam Boiler Inspection and Insurance Company, Baltimore, Maryland.
Roller, L. H., De La Vergne Machine Company, New York, N. Y.
Stevens, J. A., Chairman, Boiler Code Committee, Lowell, Mass.
Weschler, Prof. G. A., Catholic University of America, Washington, D. C.
Williams, L. C., Bureau of Engineering, Navy Department, Washington, D. C.

3. *Definitions of Technical Terms.*

Special terms used throughout this report are defined as follows:

"Code" shall be construed to be the "Preliminary Report on Rules for the Construction of Welded Pressure Vessels," Part 1, Section VI, of the A. S. M. E. Boiler Code, see Mechanical Engineering, November 1922.

"Boiler Code" is the Boiler Code as now complete.

"Regular Tanks" are those of 24 inch diameter, also three tanks,

8, 10 and 12 inches in diameter, submitted by the manufacturers in accordance with the original program.

"Special Tanks" include three tanks of 24 inch diameter and twenty tanks of 16 inch diameter, made of various thicknesses of plate and with different qualities of welds.

"Pinholes" are small holes through the material of the tank, detected during the test by a fine jet of water, while "Cracks" are small breaks through the material of the tanks, detected by a thin sheet of water.

"Intentionally defective" welds are those in the special tanks purposely made of different qualities to show the effects of poor workmanship and incorrect design.

"Breathing action" is the change in contour of the cross-section of the tank caused by changes in pressure.

II. DESCRIPTION OF APPARATUS AND TEST METHODS.

To protect the observers, an enclosure, fifteen feet long, ten feet wide and four feet high was erected, inside which the tanks were tested. A small I-beam was supported at a height of ten feet for a trolley carrying the guide pipe for the hammer, (Figs. 6, 7, 8). The tank was supported on four cast iron wheels so that it could be rotated axially by a rope to bring every portion of the circumferential head weld under the hammer. As many of the cast iron wheels broke from the shock caused by failure of the tanks, wooden discs were substituted which proved more satisfactory.

A motor driven reciprocating pump, having a plunger ½ inch in diameter and 2 inch stroke, was connected to the tanks by ⅛ inch inside diameter copper tubing. High pressure fittings were used and the tube coiled to avoid breakage when the tank was rotated. A similar connection from the other end of the tank was used for the pressure gages, as it was found that the gage needle vibrated considerably when connected directly to the pump. The pressure gages were calibrated several times during the tests and the readings corrected accordingly.

The drop hammers were made from cast iron window weights slightly rounded at the lower end. The weight of the hammer and the height of drop are given in Table 1. The hammer blows were delivered six inches apart, on or close to the welds. On some tanks, at the request of Mr. E. R. Fish of the Code Committee, a hand hammer was used as specified in the Code. In these cases the sheet was struck on both sides of the seam, alternately, a sharp vibratory blow with a 4½ pound hammer, having a twenty inch handle. The blows were struck three inches apart and within two or three inches of the seam at the rate of 50 to 60 per minute. At the suggestion of Mr. H. W. Heinrich of the Travelers Insurance Company a 12 pound sledge, having a 24 inch handle, was used on two of the tanks. The tests were much more severe than allowed by the code, as the blows dented the shell.

	Tank Nos.	Nominal Thickness	Pressure—lb/in² Working	Acceptance Test		Hammer Wgt	Hammer Drop
Regular	A—1, 2, 3	3/8 in.	250	375	250, 300, 350, 375, 400, up to 1000 by 100, up to failure by 200.	6 lb.	4 ft.
	B—1, 2, 3						
	C—1, 2, 3						
	D—1, 2, 3						
	F—1, 2, 3						
	G—1, 2, 3						
	H—1, 2, 3,						
	K—1, 2, 3, 4						
	X—13, 14 15						
	X—9, 10, 11, 12[a]					4 lb.	3 ft.
	X—20, 21, 22, 23					—None—	
Special	X—1, 2, 3, 4	10 gage	125	187½	125,, 150, 175, 187½, 200, 225, 250, 300, by 100 to 1000, by 200 up to failure.	2 lb.	3 ft.
	X—5, 6[b], 7[b], 8[c]	3/16 in.	187½	275	187½, 225, 260, 275, 310, 345, 380, 450, 525, 600, by 100 to 1000, by 200 to failure.	4 lb.	3 ft.
	X—16, 17, 18, 19	3/16 in.	187½	275		—None—	

NOTE:

a—A 4½ lb. hand hammer was used up to 500 lb/in²—6 lb drop hammer thereafter to failure—At 375 lb/in² the tank was struck rapidly on weld with 12 lb. sledge.

b—A 4½ lb. hand hammer used to 380 lb./in²—4 lb. x 3 ft. drop hammer thereafter.

c—A 4½ hand hammer up to 380 lb./in²—4 lb. x 3 ft. drop hammer to 450 lb/in²—pressure reduced to 275 lb./in² and tested with 12 lb. sledge—raised to 450 lb./in² and tested with 4 lb. x 3 ft. drop hammer to failure.

Drop hammer in Figures 6 and 7. Hand Hammer in Figure 8.

TABLE I.—Testing Conditions for Tanks.

The method of test was as follows: The pressure was raised to the acceptance pressure which was one and one-half times the working pressure, (Table I), and maintained for five minutes. The pressure was then decreased to the working pressure for three minutes and the weld hammered. The pressure was increased by the next increment, held for three minutes, the weld hammered and the test continued in this way until the tank failed.

To compare the pressure causing failure when the hammer was used and when it was not used, some of the tanks were not hammered. The test procedure for each tank is given in Table I.

III. DESCRIPTION OF THE TANKS

1. *Regular Tanks.*

The regular tanks, made from 3/8 inch mild steel were designed and welded by the methods chosen by the manufacturer. The materials were also of his choice. It was at first planned to make

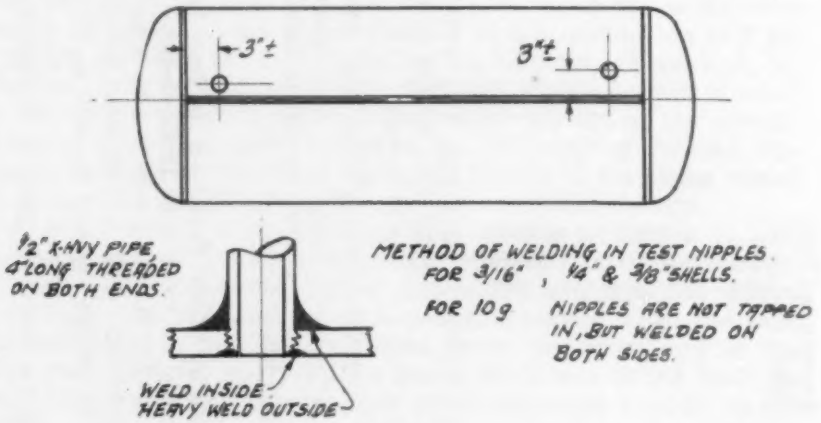

3"±
3"±
½" X-HVY PIPE 4" LONG THREADED ON BOTH ENDS.
METHOD OF WELDING IN TEST NIPPLES FOR 3/16", ¼" & 3/8" SHELLS.
FOR 10 g NIPPLES ARE NOT TAPPED IN, BUT WELDED ON BOTH SIDES.
WELD INSIDE
HEAVY WELD OUTSIDE

Figure 1.

all tanks 24 inches in diameter and 72 inches long. At the request of one member of the Committee, it was later decided to include three smaller (B) tanks. All of the tanks varied only slightly from their nominal size. A ½ inch nipple of extra heavy pipe was welded in each end of the shell, as shown in Figure 1. All regular tanks were rated by the Pressure Vessel Committee at 250 pounds per square inch working pressure. In marking these tanks, letters were assigned to each manufacturer, beginning with A. Letters E, I and J were not used.

2. *Special Tanks.*

For comparison, one member of the Pressure Vessel Committee furnished 23 special tanks which were intentionally welded to obtain welding of different qualities (Figure 2). Three of the special tanks were of the same size as the regular tanks. The

remainder were 16 in. in diameter and 36 in. long. These were made from 10 gage (9/64 in.) 3/16 and 1/4 in. sheet steel. They were in sets of four, having the same thickness, but with different qualities of welding, which were described by the maker as being, in his judgment, "bad," "poor," "fair" and "good." Welds of each

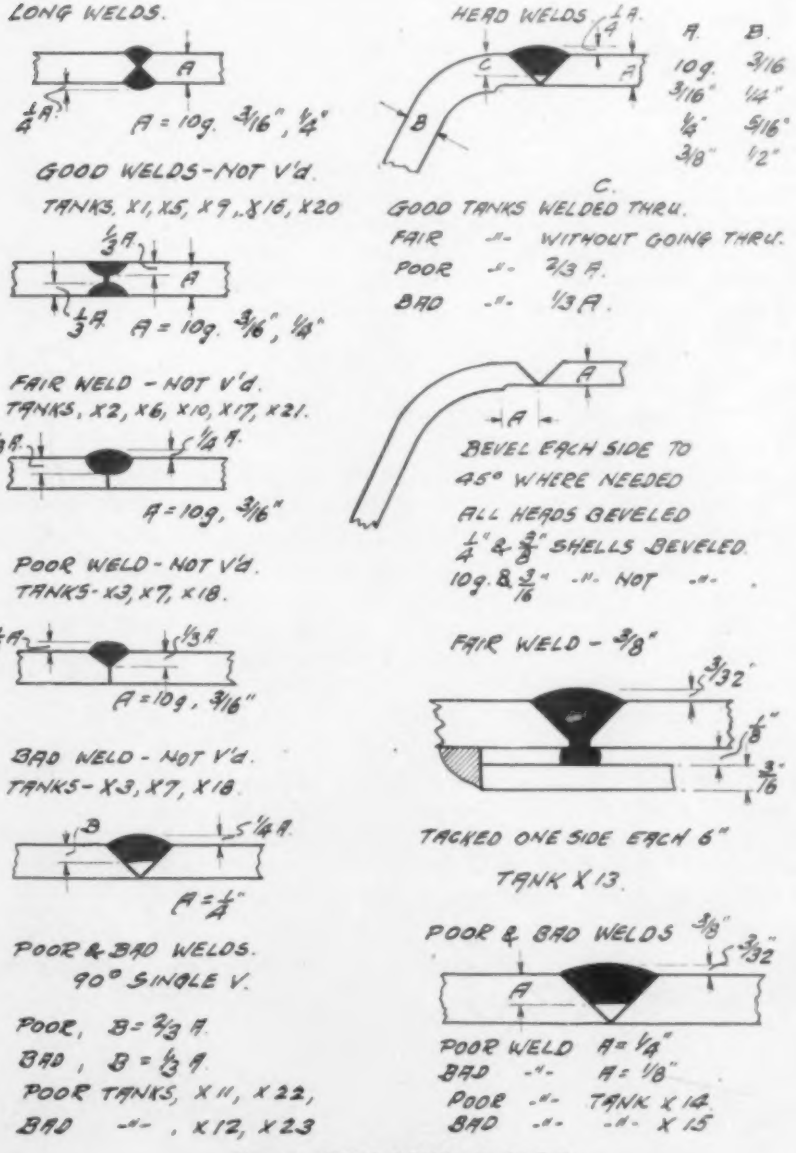


Figure 2. Method of Welding Special Tanks.

of these qualities were made in definite ways which are shown in Figure 2. It is important that this drawing be used to define accurately the design of the welds of the special tanks.

3. *Inspection Plugs in Heads.*

In some cases it is desirable to inspect the interior of tanks. Accordingly, Tank X-20 was provided with pipe flanges welded into the center of each head and closed with pipe plugs. (Fig. 5).

4. *Preheating and Annealing.*

The tank makers, in answering the question required by the Pressure Vessel Committee, stated that the tanks for this investigation were neither preheated before nor annealed after welding.

5. *Specimens.*

Each tank was accompanied by samples of the plate and welding wire used in its construction. Three tensile test specimens were cut from each sample plate, of the standard size for plate material (8 inch gage length) used by the American Society for Testing Materials. With some tanks, sample welds were furnished and test specimens cut from these also.

IV. TEST RESULTS

1. *Summary Sheets.*

The results of the tests have been grouped on the Summary Sheets—Tables 2 and 3.

NOTE: The efficiency of longitudinal welds is the ratio of the circumferential stress in the shell of the tank at failure to the average strength of the shell material shown by two test specimens.

The appearance of the tanks after test is shown by Figures 9 to 64 inclusive. The legend, in each case, gives the number of the tank followed by the pressure at failure. The outline of samples which were cut from the tanks for microscopical examination are marked with paint. If the tank failed under the hammer, the location of the last blow was marked with an "X."

2. *Photographs.*

Photographs showing the fracture in greater detail were obtained for many of the tanks, and are accompanied by comments on any unusual features of the test or the way in which failure occurred. Figures 65 to 71 show tensile specimens of plate material. Figure No. 72 shows all the tanks after test.

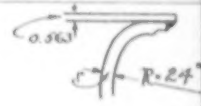
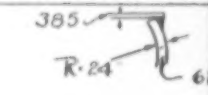
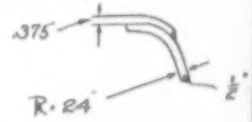
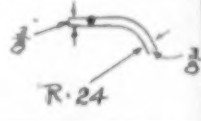
3. *Microscopical Examination.*

Following the photographs are the results of the microscopical examination.

V. DISCUSSION OF RESULTS

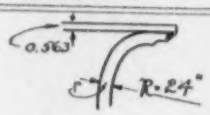
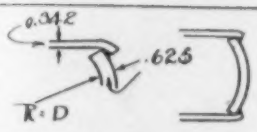
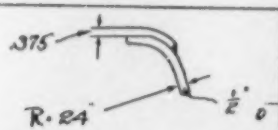
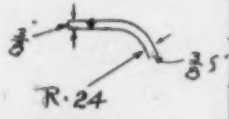
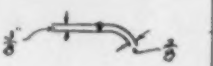
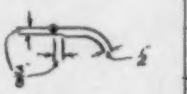
1. *Types of Construction.*

For the purpose of discussing the test results, it is convenient to note the following typical differences in design:

TANK	PLATE											
	CHEMICAL ANALYSIS					PHYSICAL PROPERTIES						
NO.	C.	MN.	P.	S.	SI.	YIELD POINT LB. PER SQ. IN.	ULT. TEN. STR. LB. PER SQ. IN.	RED. AREA PER CENT	ELONG PER CENT.	KIND	VEE [f]	CONSTRUCTION
A-1	.067	.390	.007	.029	trace	33 300 [d]	50 300 [d]	55.0 [d]	30.0 [d]	E	None	
2	.060	.381	.006	.028	"	30400 [d]	57 100 [d]	58.5 [d]	30.5 [d]	E	"	
3	.084	.372	.006	.031	"	31000 [d]	49 300 [d]	59.5 [d]	30.5 [d]	E	"	
B-1	.049	.021	.200	.017	0.17	- [d]	34 700 [d]	- [d]	- [d]	G	"	
2	.015	.012	.251	.018	0.13	- [d]	36600 [d]	- [d]	- [d]	G	"	
3	.044	.330	.085	.013	0.038	39 600 [d]	61 300 [d]	45.0 [d]	17.0 [d]	G	"	
C-1	.257	.360	.010	.021	trace	33100	60200	49.5	27.1	E	Single	
2	.255	.366	.012	.017	"	33000	59800	50.7	24.9	E	"	
3	.240	.357	.011	.022	"	33300	59600	50.3	24.4	E	"	
D-1	.084	.405	.006	.032	"	30200 [d]	48200 [d]	44.1 [d]	27.1 [d]	E	None	
2	.160	.411	.008	.058	"	38900 [d]	54900 [d]	51.6 [d]	24.1 [d]	G	"	
3	.135	.384	.011	.038	"	33900 [d]	48900 [d]	39.9 [d]	19.2 [d]	E	"	
F-1	.095	.276	.007	.015	"	28 600	49100	57.0	31.7	E	Single	
2	.085	.318	.009	.015	"	33000	48900	59.9	32.5	G	"	
3	.100	.300	.007	.018	"	29100	48900	58.6	31.3	G	"	
G-1	.105	.366	.009	.041	"	30900	49400	56.8	33.2	G	Double	
2	.120	.381	.010	.037	"	30500	49800	59.6	31.5	E	"	
3	.116	.354	.010	.040	"	32000	49900	61.8	33.8	E-out G-in	"	
H-1	.120	.432	.022	.026	"	29900	49200	55.4	32.5	G	Single	
2	.126	.420	.020	.020	"	29500	48700	59.8	32.9	G	"	
3	.120	.402	.017	.022	"	29800	49900	60.7	31.3	G	Double	
K-1	.080	.387	.008	.019	"	28900	52300	60.4	353	G	"	
2	.053	.393	.026	.018	"	31130	52870	58.5	33.2	G	"	
3	.064	.399	.028	.019	"	31800	51000	62.0	30.6	G	"	
4	.115	.405	.032	.025	"	30950	51500	59.0	32.3	G	"	

[f] denotes longitudinal weld [d] test specimens taken from pipe sections [a] Larger denotes open circuit

TABLE II ~ SUMMARY OF TESTS ON WELDED PRESSURE VESSELS. — REGULAR

CONSTRUCTION	WELD: WIRE DIAM. IN.	CHEMICAL ANALYSIS: C.	Mn.	P.	S.	Si.	Ni.	TORCH SIZE	CURRENT: AMPS	VOLTS[a]	DIAM IN.
	3/16	.067	.108	.025	.015	trace	trace	—	150/200	80	24 O.D
	"	"	"	"	"	"	"	—	150/200	80	"
	"	"	"	"	"	"	"	—	150/200	80	"
	1/4	.020	.132	.006	.029	"	"	0-10	—		80.D
	"	"	"	"	"	"	"	0-12	—	-	100.D
	"	"	"	"	"	"	"	0-12	—	-	12 O.D
	3/16	122	.486	.022	.013	"	"	—	160/190	20/25	24 I.D
	5/32	.147	.546	.024	.024	"	"				
	3/16	.122	.486	.022	.013	"	"	—	160/190	20/25	"
	5/32	.147	.546	.024	.024	"	"				
	3/16	.122	486	.022	.013	"	"	—	160/190	20/25	"
	5/32	.147	.546	.024	.024	"	"				
	5/32	.014	.018	.005	.015	"	"	—	150/175	65	24 O.D
	1/4	.024	.021	.006	.025	"	"	0-12	—	-	"
	5/32	.020	.018	.005	.026	"	"	—	150/175	65	"
	3/16	089	405	025	.028	"	"	—	150	65	24 ID
	5/32	033	.105	.027	.023	"	"	0-10	—	-	"
	"	"	"	"	"	"	"	0-10	—	-	"
	1 1/4	033	105	.009	.023	"	"	R-6	—	-	"
	165	.145	.651	.024	.032	"	"	-	150	60	"
	165 + 3/16" + 1/4	.145	651	.024	.032	"	"	R-6	150	60	"
		.033	105	.009	.023	"	"				
	1/4	.033	.105	.011	.023	"	"	M-7-M-8	-	-	"
	"	"	"	"	"	"	"	M-7-M-8	-	-	"
	"	"	"	"	"	"	"	M-7-M-8	-	-	"
	"	.053	.084	.005	.029	"	.1202	D-8-D-7-D-8	-	-	"
	"	.127	.822	.008	.015	.260	trace	D-8-D-7 D-8	-	-	"
	"	.267	552	.031	017	.120	3.60	D8 D-7-D-8	-	-	"
	"	.102	459	.026	.031	trace	trace	2	125	60	"

[a] ...er denotes open circuit voltage, smaller arc voltage. H denotes failure in head, L denotes

EGULAR.

Corrected Tab

TANK

Diam. In.	Thickn's In	Pressures Lb. per Sq. In. Working	Leakage	Failure	Stresses Lb. per Sq. In. Nominal Working	Leakage	Failure	Increase Circum. In.	Eff'y Weld%
24 O.D.	0563	250	1710	1710 H	5100	34700	34700	1-5/8	69.0
"	0579	"	900	1200 H L	4900	17800	23700	1/2	41.5
"	0566	"	1480	1600 H	5000	29900	32300	1-5/8	65.6
8 O.D.	0.342	"	-	2400 L	2700	-	25700	0	74.0
10 O.D	0362	"	-	2150 L	3200	-	27600	1/8	75.3
12 O.D.	0.379	"	-	2150 H	3700		31900	1/8	52.0
24 I.D.	0387	"	150	1200 * H	7800	4600	37200	5/8	61.9
"	0382	"	1000	1080 H	"	31400	33900	1/8	56.7
"	0385	"	375	1400 H	"	11700	43600	1-1/16	73.2
24 O.D.	0365	"	1600	1600 * L	8000	51000	51000	6-1/8	105.7
"	0383	"	-	- H	7600	-	-	-	-
"	0395	"	900	1160 H	7400	26400	34100	3/4	69.7
24 I.D.	0.410	"	-	1200 * L	7300	-	35100	0	71.5
"	0.399	"	-	1475 L	7500	-	44400	1-1/8	90.7
"	0.405	"	-	975 L	7400	-	28900	0	59.1
"	0381	"	-	1400 * L	7900	-	44100	2-0	89.3
"	0.352	"	-	1660 H	8500	-	56600	6-5/8	113.6
"	0.349	"	-	1400 * L	8600	-	48100	2-3/16	96.4
"	0368	"	-	1575 L	8200	-	51400	2-0	104.5
"	0.351	"	-	1320 L	8600	-	45100	1-3/16	92.7
"	0.384	"	-	1800 * L	7800	-	56200	3-3/4	112.
"	0370	"	-	1600 * L	8100	-	51900	3-1/8	99.2
"	0388	"	-	1660 L	7700	-	51400	2-1/2	97.1
"	0.382	"	-	1600 * L	7800	-	50200	1-7/16	98.5
"	0.388	"	-	300 * H	7700	-	9300	0	18.0

denotes longitudinal failure in shell. * denotes failure under hammer.

TABLE III — SUMMARY OF TESTS ON WELDED PRESSURE VESSELS. — SPECIAL.

Tank No.	PLATE Physical Properties: Yield Point lb. per sq. in.	Ult. tensile str. lbs. per sq. in.	Red. area Per cent	Elong. [c] Per cent	WELD: Kind	Grade [b]	Wire Diam. In.	Torch Size	Ult. tensile strength of welded specimen lbs. per sq. in.	TANK: Diam. In.	Thickness In.	Pressures lbs. per sq. in. Working	Leakage	Failure		Stresses lbs. per sq. in. Working	Leakage	Failure	Eff. Weld %	Figure No.	Tank No.
X- 1	47900	54350	53.0	15.0	G	Good	1/8	D4-D4 –	54000	16	0.140	125	–	990	L	7100	–	56600	104.0	42	X- 1
2	55250	63600	50.5	11.9	"	Fair	"	D4-D4 –	49900	"	"	"	–	880	L	7100	–	50300	79.1	42-43	2
3	56300	62600	52.3	10.0	"	Poor	"	– D4-D4	42600	"	"	"	–	500	★ L	7100	–	28600	45.6	42	3
4	55450	61200	52.5	10.0	"	Bad	"	D4-D4-D4	46400	"	"	"	–	600	L	7100	–	34300	56.1	42-44	4
5	41250	50700	61.4	22.5	"	Good	"	D4-D4-D4	51500	"	0.195	187½	225	1075	H	7700	9200	44100	87.0	45	5
6	38400	51500	59.7	26.3	"	Fair	3/16	D5-D5-D5	47300	"	"	"	–	1150	L	7700	–	47200	91.6	45	6
7	46000	56650	54.3	19.4	"	Poor	1/8	D5-D5-D5	42600	"	"	"	–	900	L	7700	–	36900	65.2	45	7
8	43450	54400	54.4	15.6	"	Bad	1/8	– D4-D4	32900	"	"	"	–	450	★ L	7700	–	18500	33.9	45	8
9	36300	52400	54.1	28.2	"	Good	3/16	D5-D5-D5	50000	"	0.250	250	225	1880	L	8000	7200	60200	114.8	46-47	9
10	37000	52700	51.0	28.8	"	Fair	"	D5-D5-D5	45400	"	"	"	–	1390	L	8000	–	44500	84.4	46-48	10
11	38200	52850	54.5	28.2	"	Poor	"	– D5-D5	37800	"	"	"	–	900	★ L	8000	–	28800	54.5	46	11
12	33000	47750	61.0	28.8	"	Bad	"	– D5-D5	37600	"	"	"	–	900	★ L	8000	–	28800	60.3	46-49	12
13	30650	48350	62.9	34.4	"	Fair	1/4	– D8-D8	49200	24	0.378	"	–	1170	L	7900	–	37200	76.8	50-51	13
14	31800	50350	59.1	31.9	"	Poor	"	– D7-D8	40500	"	0.369	"	–	500	★ L	8100	–	16300	32.3	52	14
15	29600	47500	63.6	34.4	"	Bad	"	– D7-D8	29800	"	0.389	"	–	300	★ L	7700	–	9200	19.5	53	15
16	42750	54950	45.6	13.8	"	Good	1/8	D5-D5-D5	51000	16	0.195	187½	–	1370	L	7700	–	56200	102.3	54	16
17	42550	55400	47.9	20.6	"	Fair	"	D4-D4-D4	44700	"	"	"	–	1140	L	7700	–	46800	84.4	54	17
18	39750	53500	60.7	25.7	"	Poor	"	– D4-D4	43300	"	"	"	–	580	L	7700	–	23800	44.4	54	18
19	42500	53750	58.5	20.6	"	Bad	"	– D4-D4	44200	"	"	"	–	600	L	7700	–	24600	45.8	54	19
20	34150	50100	60.3	24.4	"	Good	3/16	D5-D5-D5	50100	"	0.250	250	400	1650	P	8000	12800	52800	105.4	55-56	20
21	35150	52100	59.9	25.0	"	Fair	"	D5-D5-D5	52100	"	"	"	–	1560	L	8000	–	49900	95.8	55-57	21
22	34600	50200	61.8	30.7	"	Poor	"	D4-D4-D5	34100	"	"	"	–	1020	L	8000	–	32600	65.0	55-58	22
23	35050	48400	60.1	26.3	"	Bad	"	D5-D5-D5	32200	"	"	"	600	650	L	8000	19200	20800	43.0	55	23

b See Figure for details.
c 8 inch test specimen used.

★ Denotes failure under hammer. L Longitudinal failure in shell.
P Denotes leakage around plug.

(a) *Shell Construction.*

Pipe

Shell made of commercial pipe, presumably having a longitudinal weld.

Single Vee Weld

Commercial plate rolled to shape and welded with a longitudinal single Vee weld.

Double Vee Weld

Commercial plate rolled to shape and welded with a longitudinal double Vee weld

(b) *Head Construction.*

Inserted Heads

Heads inserted in the shell and welded as shown in Table II, by A, B, C, and D. Note that in the A tanks the heads are convex to the pressure.

Butt Welded Heads

Heads dished, flanged and butt welded to shell as shown in Table II, by F, G, H, and K. The closing head necessarily had a single Vee weld. In one case (G-tanks) the first head had a double Vee weld.

2. *Types of Failure.*

In interpreting the pressure and shell stress at failure, it is necessary to distinguish between longitudinal failure in the shell (including the longitudinal weld) and failure in the head (usually at the head weld). Where failure took place in the shell the pressure and the stress computed from it are a measure of the strength of the shell (including the longitudinal weld) but where failure took place in the head, the only conclusion to be drawn is that a higher pressure and stress would be necessary to cause shell failure. Similarly, where failure took place in the head, the corresponding computed shell stress is a measure of the strength of the head construction, but where failure took place in the shell, the only conclusion to be drawn is that is would have required a stronger shell and higher shell stress to cause failure in the head.

Other differences in the kind of failure may be noted. Sometimes leaks (pinholes or cracks) developed. When these were small, the pressure could be increased until the tank failed by sudden rupture. When the leaks were too large or increased in size too rapidly, the capacity of the pump was insufficient to cause rupture. Where no leaks developed, the tanks failed by sudden rupture.

In some cases the head was blown completely out of the tank; in others the rupture was confined to a part of the circumference and in others the failure was due to excessive leakage in the weld. Longitudinal failure in tanks with a longitudinal weld took place, either in the weld, adjacent to the weld, and in some of the special

tanks about two inches from the weld, or a combination of these. The failure varied from a short crack to a rupture of the whole length of the tank and sometimes extending into the head.

In all cases of shell failure, single Vee longitudinal welds failed either wholly or partially in the center of the weld.

Three out of eight double Vee welds (omitting K-4 retest) in the regular tanks (G-1, K-1, K-2), failed partially in the center of the weld.

In the special tanks, all of the "fair" double Vee welds failed either wholly or partially in the center of the weld, while none of the "good" double Vee welds failed in the weld.

Details of all these failures are noted in the comments accompanying the photographs.

It may be noted that none of the nipples, all of which were welded as shown in Figure 1, failed or developed leaks in any of the tests.

3. *Pressure and Stresses at Failure.*

(a) Longitudinal Failure in Shell.

In Figure 3 are plotted the pressures at which all the 24 inch regular tanks failed. These are arranged in three groups corresponding to the three types of shell construction.

This figure shows clearly that the double Vee weld is superior to the single Vee weld in the longitudinal seam. Only two of the single Vee welds failed at a higher pressure than the lowest of the double Vee. In addition the double Vee welds give much more uniform results showing a maximum variation of 13 per cent from the average, while the single Vee shows a variation of 24 per cent. The large proportion of failures in the head make it inadvisable to draw a similar comparison for the pipe tanks.

Figure 3 shows the pressures of the 24 inch regular tanks at failure, while in Figure 4 are plotted the stresses at which all of the tanks failed (excluding retests). These are arranged in seven groups; three for the regular tanks corresponding to the three types of shell construction and four for the special tanks corresponding to "bad" and "poor" (single Vee) and "fair" and "good" (double Vee) welds. The "fair" single Vee weld (X-13) is plotted with the "poor" welds.

This figure also shows the superiority of the double Vee welds. Only two, H-1 and H-2, of the single Vee welds failed at a higher stress than the lowest of the double Vee welds. The double Vee welds as in Figure 4 give more uniform results than the single Vee, whether in the regular tanks or in the special tanks. This is especially noticeable for intentionally defective welded "fair" double Vee welds which give results not much lower than the corresponding "good" welds. Although the design for the double Vee "fair" welds required one-third of the thickness of the plate to be unwelded, the strength of these welds was not much lower than that of the "good" welds, which were of double Vee

design and welded through the plate. The imperfect character of these "fair" welds can be seen in X-10, Figure 71.

A comparison for the pipe shells is unnecessary because of the large number of failures in the head, but the low stresses obtained from the tanks B-1 and B-2 contrasted with the high value from

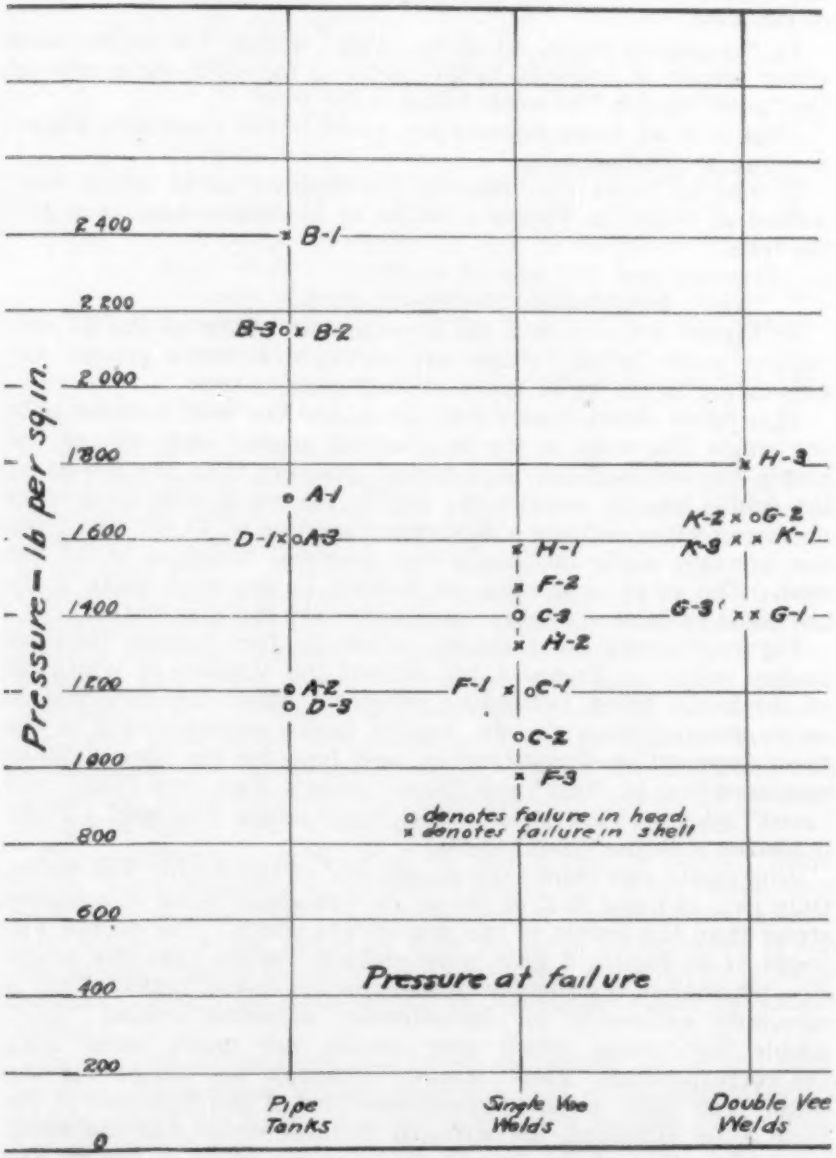


Figure 3.

D-1 suggests that the pipe shells were much more variable than the double Vee welded plate shells.

(b) Failure in Head.

. It is possible to draw certain definite conclusions from the failures in the head. Excluding two cases of small leaks (K-4 and

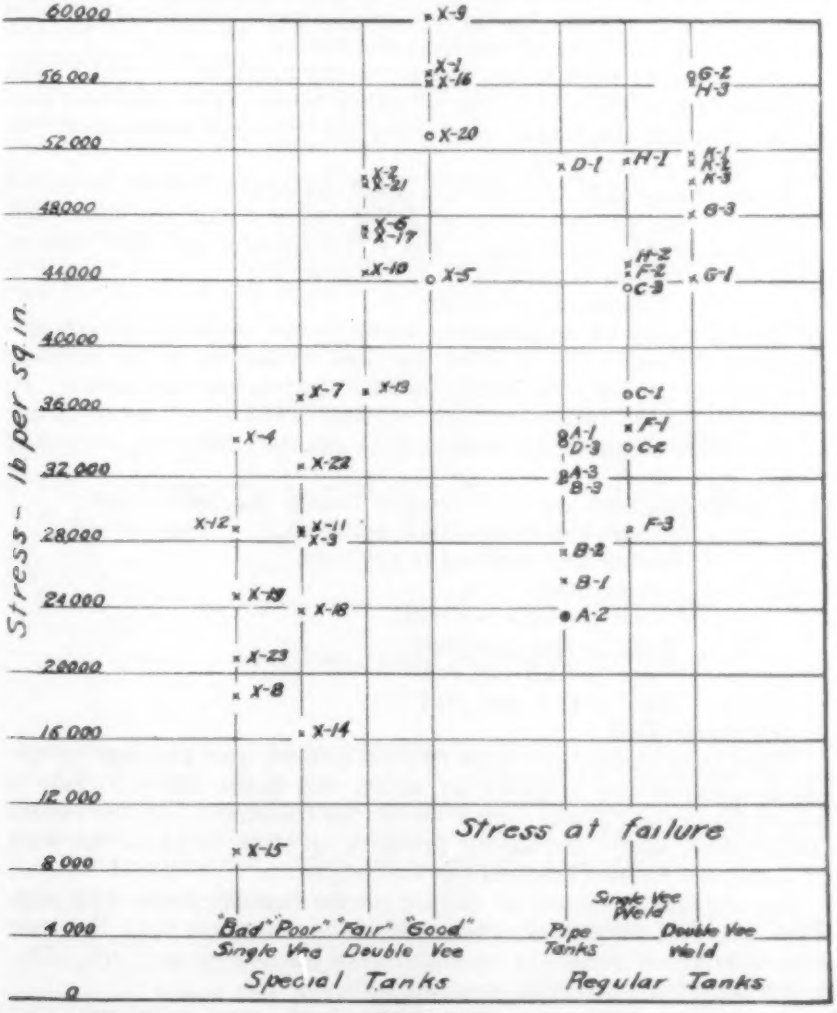


Figure 4.

X-5), only one of the tanks (G-2) with butt welded heads, failed in the head. This failed after large deformation had taken place, (Figure 4), at a stress higher than the two corresponding tanks (G-1 and G-3), and above the average for all tanks of the same type. This does not indicate a serious weakness of this head.

On the other hand all except one of the tanks (D-1) with inserted head failed at stresses below all except the two (F-1 and F-2) lowest of the tanks with butt welded heads and nine out of twelve failed in the head. It is probable that the inserted head is relatively weaker than the butt welded head. Since the A tanks had much thicker shells and the B tanks much smaller diameters than the other regular tanks, this conclusion is less certain than if all the tanks had been of identical dimensions.

The A tanks, with heads convex to the pressure showed a type of head failure different from all other tanks. The pressure partially reversed the heads, stretching the rim and developing tension cracks in the weld.

Whether this type of failure is disadvantageous cannot be stated certainly, but the low stress at failure of A-2 and the difference (32.0 per cent) between A-1 and A-2 suggests that this type of head construction is especially unreliable.

(c) Efficiency of Welds.

The efficiency of longitudinal welds is the ratio of the circumferential stress in the shell of the tank at failure to the average strength of the shell material shown by three test specimens. In cases where head failure occured, all that is known of the efficiency of the longitudinal weld is that it is greater than the computed values.

For the different types of regular tanks, the results are

Single Vee weld—76.3 per cent.
Double Vee weld—101 per cent.

For the special tanks:

"Good"—102.7 per cent.
"Fair"—85.4 per cent.
"Poor"—51.2 per cent
"Bad"—43.1 per cent.

4. *Hammer Test.*

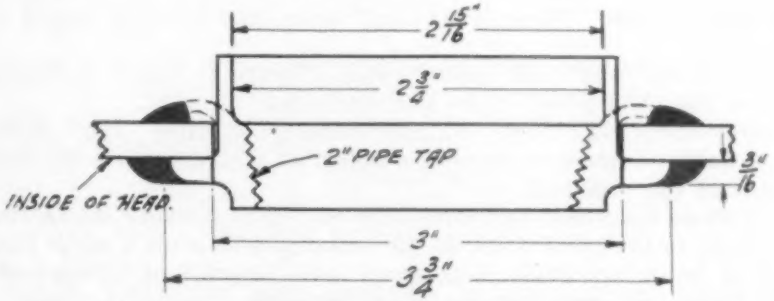
There is no indication, with two exceptions, that hammering the tanks lowered the pressure at which the tanks failed. Only 9 out of 25 regular tanks failed under the hammer. All the others failed either under increasing pressure or (two only) in the wait of 3 minutes before hammering was begun.

The average pressure at failure of the regular tanks (3/8 inch shell 24 inch diameter) under the hammer was 1344 lbs. per square inch; not under the hammer, 1470 lbs. per square inch. The difference of 8.6 per cent is not significant.

In addition, one set of four special tanks was hammered and the results compared with a duplicate set, which was not hammered. The 3/16 inch shell withstood an average pressure of 894 lbs. per square inch, hammered (X-5 to X-8) and 923 lbs. per square inch unhammered (X-16 to X-19). For the 1/4 inch shell, the average pressures were 1268 lbs. per square inch hammered (X-9 to X-12) and 1220 lbs. per square inch unhammered, (X-20 to X-23).

The results from the four special tanks (X-6, X-7, X-8 and X-12), which were tested in accordance with the Code, are included in these averages. In addition the tanks X-8 and X-12 were hammered with a heavier hammer (12-lb.) than is prescribed by the Code and more severely, (denting the shell) than is allowed by the Code. The pressures at which these tanks failed are, on the average, higher than is the case for the corresponding unhammered tanks.

Two of the tanks, however, after carrying the static acceptance pressure, showed defects under the hammer at a lower pressure. One of these, the regular tank K-4, developed a slight crack in the head weld at a pressure of 300 pounds per square inch. The other was an intentionally defective "bad" welded single Vee tank X-15, in which the weld opened for nearly half its length under a pressure of 300 pounds per square inch. In these cases, only, did the hammer test disclose a defective weld.



INSPECTION SLEEVE IN HEADS OF TANK X-20.

Figure 5.

In the tank K-4, the failure was a crack in the head weld about 5 inches long. This was not accompanied by distortion of the head or shell and the microscopical examination showed that it was probably caused by contraction of the metal in cooling from a high temperature. (See microscopical examination).

5. *Hydrostatic Test Pressure.*

Only one (K-4) of the regular and three (X-5, X-9 and X-15) of the special tanks showed any defect below the acceptance pressure (1½ times the working pressure). Tank K-4 had a local defect in the head weld, producing leakage. This was afterward repaired, as is allowed by the Code, and on retest the tank failed at 1600 lbs. per square inch, 6.4 times the working pressure.

The defects shown at low pressure in the tanks X-5 and X-9 were leaks smaller than the capacity of the pump so that the pressure was increased without repairing the leaks, until the shell stresses were higher than the yield point of the shell material. The

repair of these leaks would have been allowed by the Code.

The tank X-15 had an intentionally defective "bad" weld. As the special tanks included eighteen tanks with imperfect welds (See Figure 2), of which only three showed defects at 1½ times the working pressure, it is evident that this test pressure cannot be relied upon to show imperfect welds, even when hammered.

On the other hand, pressures, which caused shell stresses below the yield point of the material, showed defects in seven of the regular tanks. Five of these were leaks which could have been repaired under the Code. They were not large enough to prevent the pressure being raised until the tank failed at a shell stress above the yield point of the material. Head failure took place in the other two. Sixteen of the twenty-three special tanks showed defects at shell stresses below the yield point of the material. Three of these (X-5, X-9, X-20) had "good" welds, (Figure 2). These showed small leaks which did not prevent the pressure being raised until the tank failed at a shell stress above the yield point of the material. These leaks could have been repaired under the Code.

All of the "bad" and "poor" welds (Figure 2) failed at stresses below the yield point of the shell material.

Only one (X-2) of the six intentionally defective "fair" double Vee welds (Figure 2) showed a defect at a stress above the yield point of the material.

It seems clear that pressures high enough to produce shell stresses equal to the yield point of the material will show a large number of imperfect welds; both small leaks, capable of repair under the Code, and gross defects which seriously weaken the tank.

On the other hand, even such pressures can not be relied upon to show incomplete fusion at the centers of a double Vee weld. Whether this incomplete fusion is a serious defect has not been determined. These welds show somewhat lower stresses at failure than the corresponding "good" welds but the pressures at which failure took place ranged from 4.7 to 6.2 times the working pressures.

6. *Yield Point Stresses in Hydrostatic Test.*

The results, so far discussed, make it desirable to investigate if a permanent deformation produced by hydrostatic pressure weakens a tank. Four 3/16 inch shell tanks were selected for repair and retest. One of these (X-5) having a "good" weld and one (X-6) having a "fair" weld developed small leaks in the first test. Local repairs were made at the leaks. The heads of the other two (X-18 and X-19) were cut off and the tanks entirely rewelded with "good" welds.

All were subjected to a pressure which produced a permanent increase of ¼ inch, (approximately ½ per cent) in the circumference of the tank. Two (X-5 and X-18) were immediately test-

ed to destruction. The others (X-6 and X-19) were set aside for two days and retested. The pressures at failure were 1330, 1440, 1330 and 1375 lbs. per square inch, respectively. The values for the original tests on the corresponding tanks X-5 and X-16 with "good" welds were 1075 and 1370 lbs. per square inch, respectively. There is, therefore, no indication that a hydrostatic test to pressures which cause a small permanent deformation weakens the tank. This suggests that a pressure producing a small permanent increase in the circumference of the tank may be desirable in an acceptance test.

7. *Test of Inspection Plugs*

In the first test the plugs in tank X-20, leaked around the threads at a pressure of 300 lbs. per square inch. The pressure was released, the plug removed, white-leaded, and replaced. The thread then leaked slightly at 400 lbs. per square inch. A pin hole developed in the weld at 1350 lbs. per square inch, another at 1500 lbs. per square inch, both of which leaked excessively at 1650 lbs. per square inch.

These pinholes were rewelded and the tank again tested, failing outside the longitudinal weld at 1730 lbs. per square inch.

This shows that inspection plugs can be inserted in the heads without weakening the tank.

VI. CONCLUSIONS

The results of these tests warrant the following conclusions:

1. The double Vee weld is much superior to the single Vee weld.
2. The pipe shells tested were less uniform and averaged lower in strength than double Vee welded plate shells. This should be investigated further.
3. The butt welded heads were stronger than the inserted heads.
4. A hammer test cannot be relied upon to show more than a very few exceptionally defective welds.
5. The hammer test, as applied, apparently did not weaken the tanks.
6. Hydrostatic pressure 1½ times the working pressure showed only a small number of imperfect welds, even when the hammer was used.
7. Hydrostatic pressure sufficient to stress the shell to the yield point will show a large proportion of imperfect welds.
8. Hydrostatic pressure sufficient to produce a permanent set in the shell, enlarging the circumference ½ per cent, apparently does not weaken the tank.
9. Flanges for inspection plugs can be welded in the heads of a tank without weakening it.

Respectfully submitted,

F. C. BROWN,

Acting Director

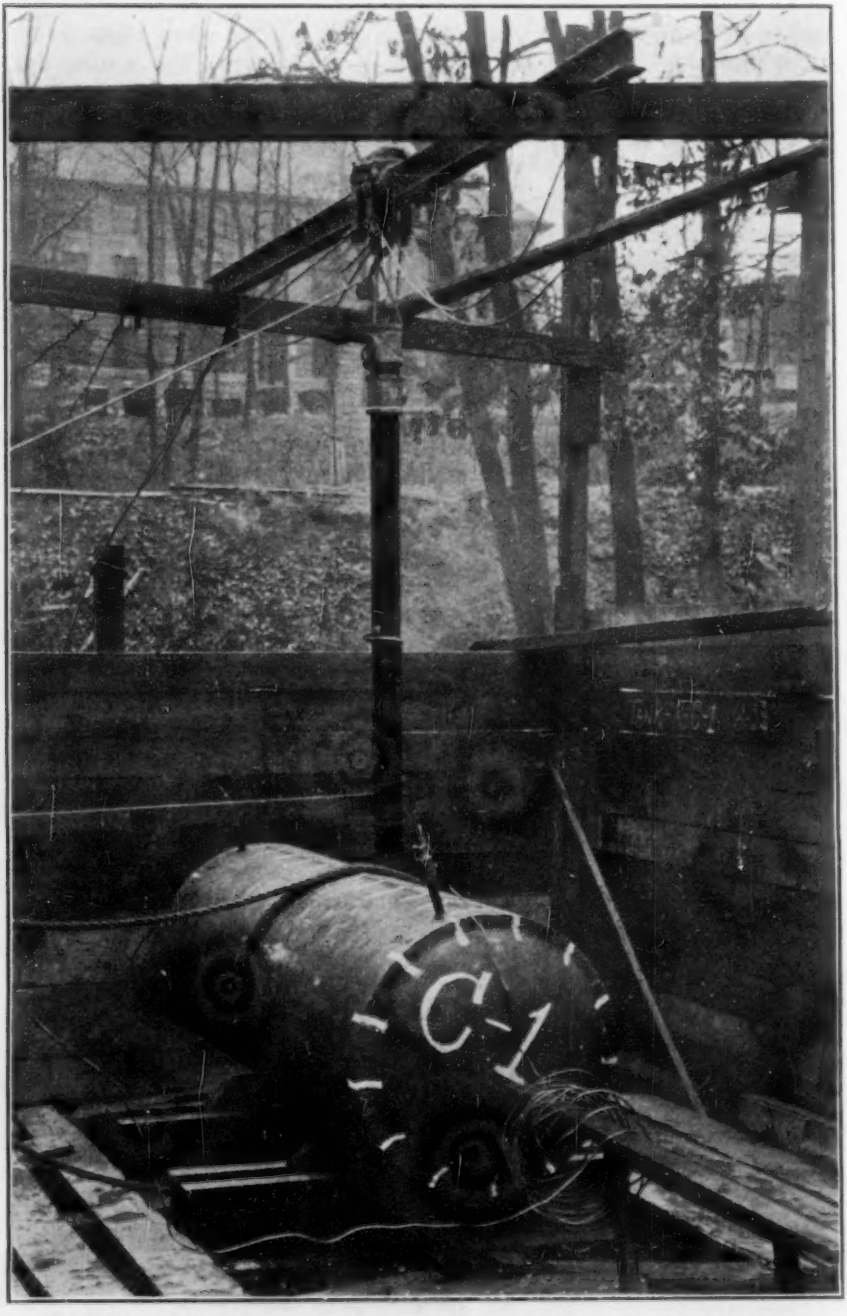


Figure 6. This figure illustrates in detail the test arrangements, including drop hammer and guide pipe, marks for locating hammer blows, rollers and rope for rotating tank, and copper tube connection to pump and gage.

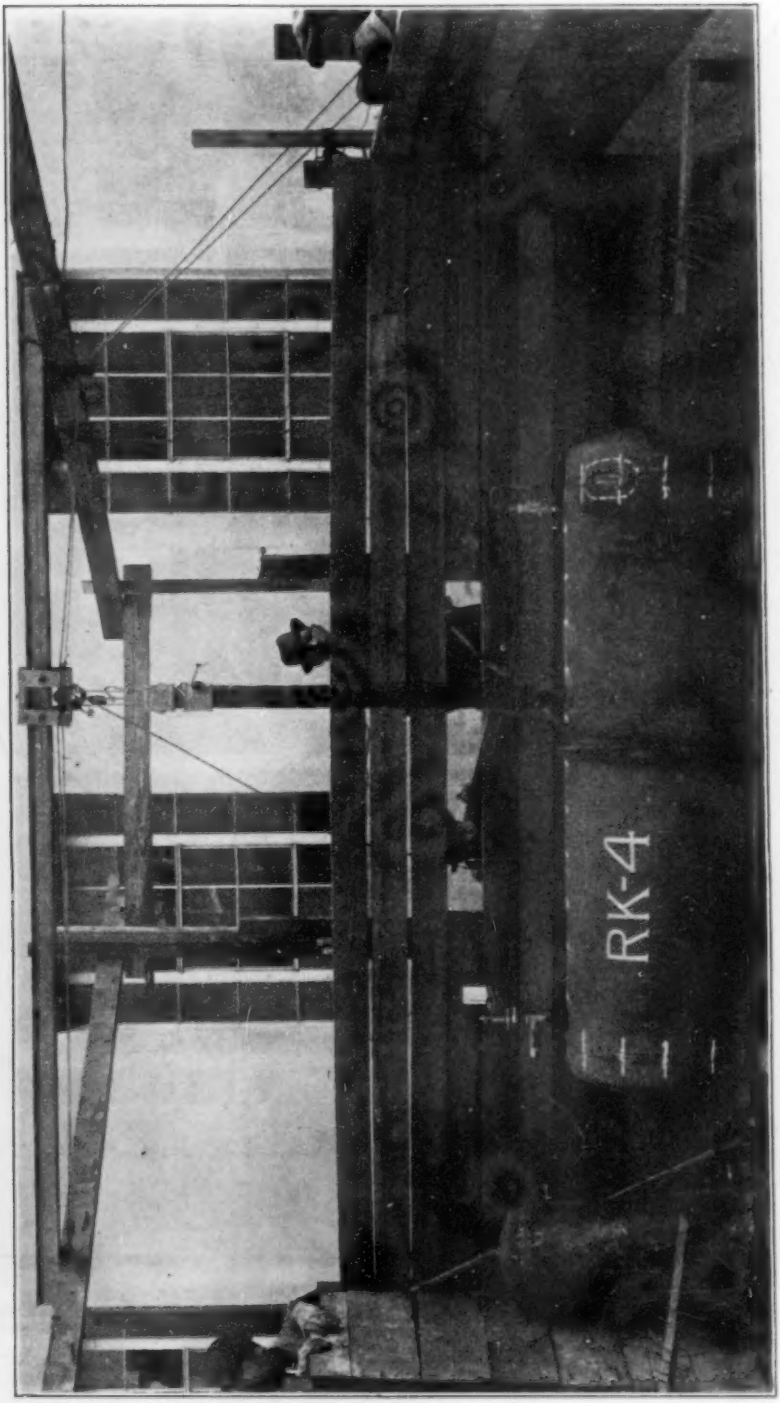


Figure 7. Another view of the wreden enclosure built around the tanks and details of the test arrangements.

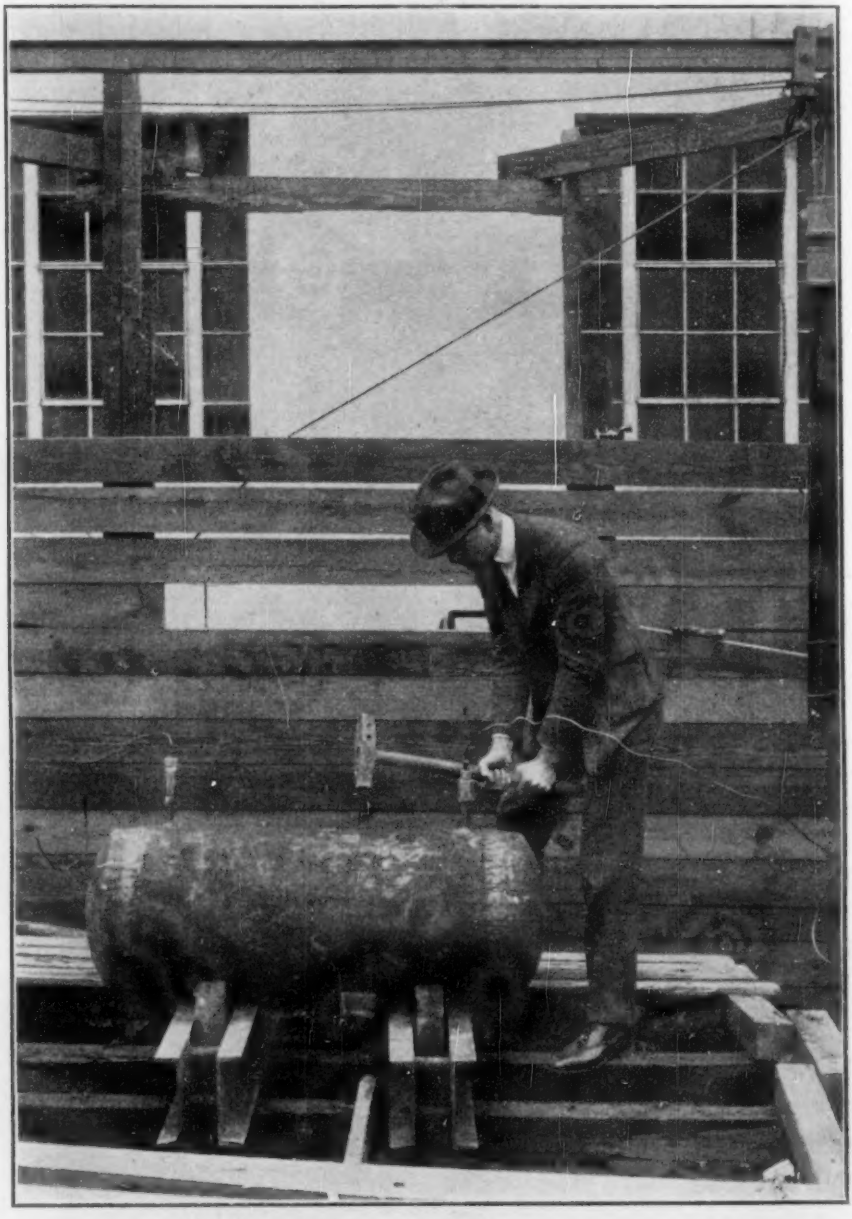
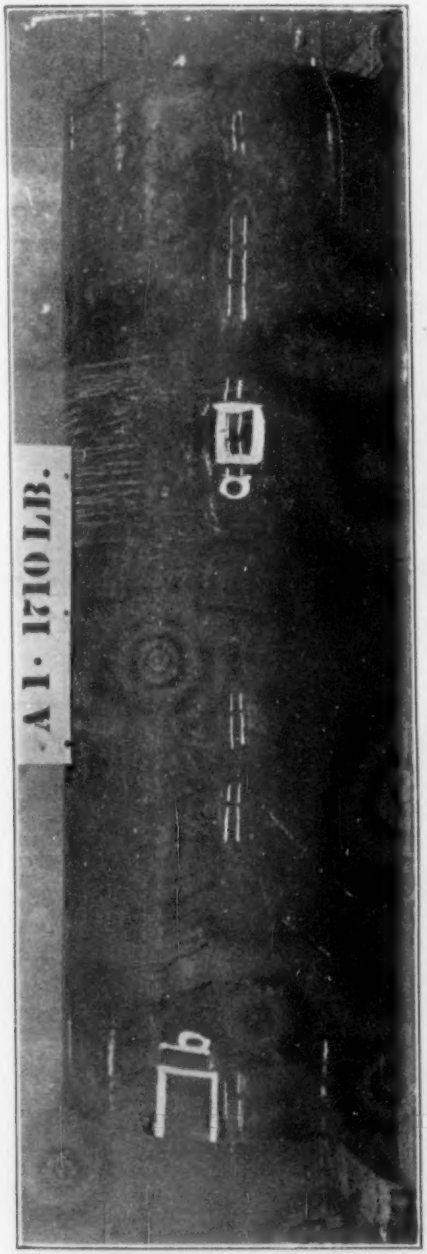


Figure 8. Application of the code hammer test. This figure shows a close-up of the rollers used for rotating tanks.



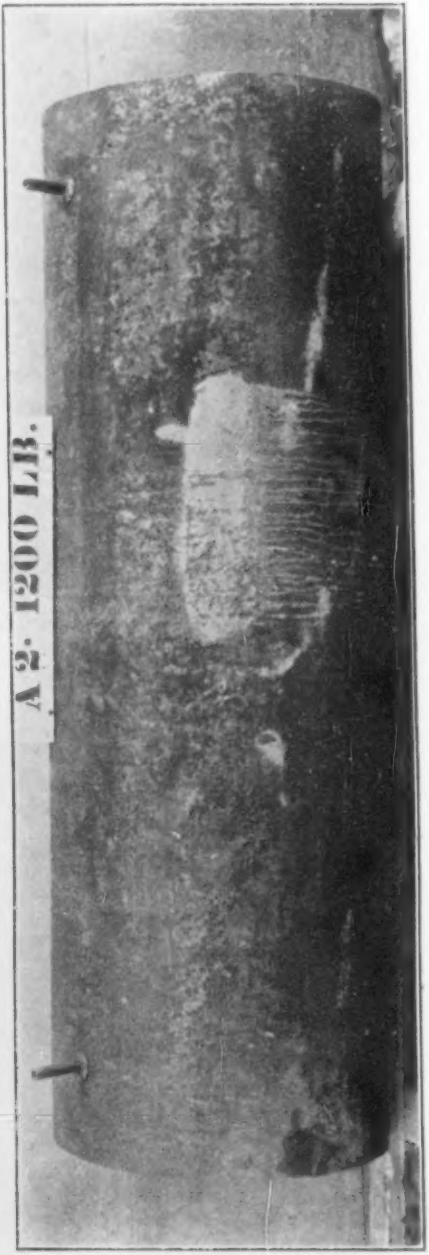


Figure 9. (Left-hand figure—Tank A-1. Head failed before rupture of shell. Figure shows small cracks appearing (between chalk marks) on shell.

Figure 10. The right-hand figure shows Tank A-2, which failed at 1200 lbs. Failure occurred both in head and longitudinal seam.

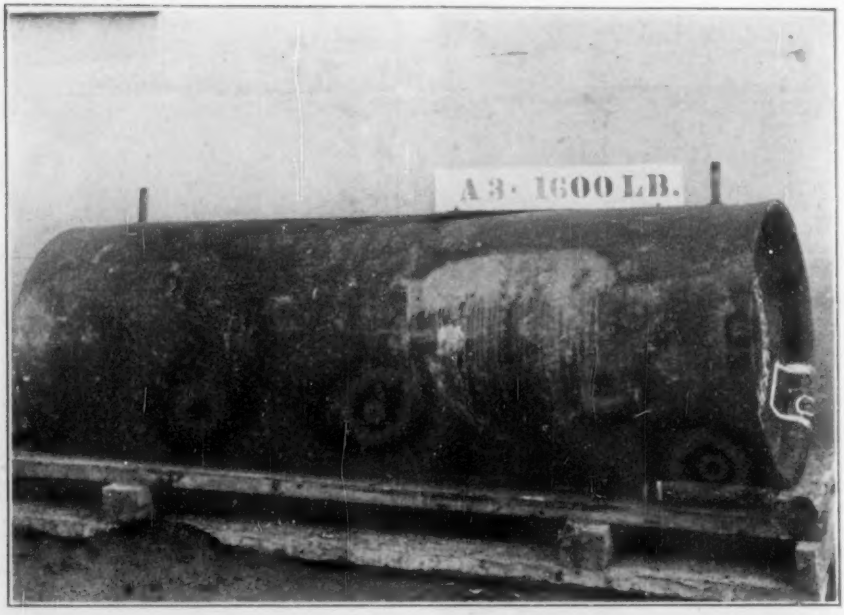


Figure 11. Typical head failure of "A" tanks by partial reversal head, flaring of end of shell and opening of tension cracks in weld.

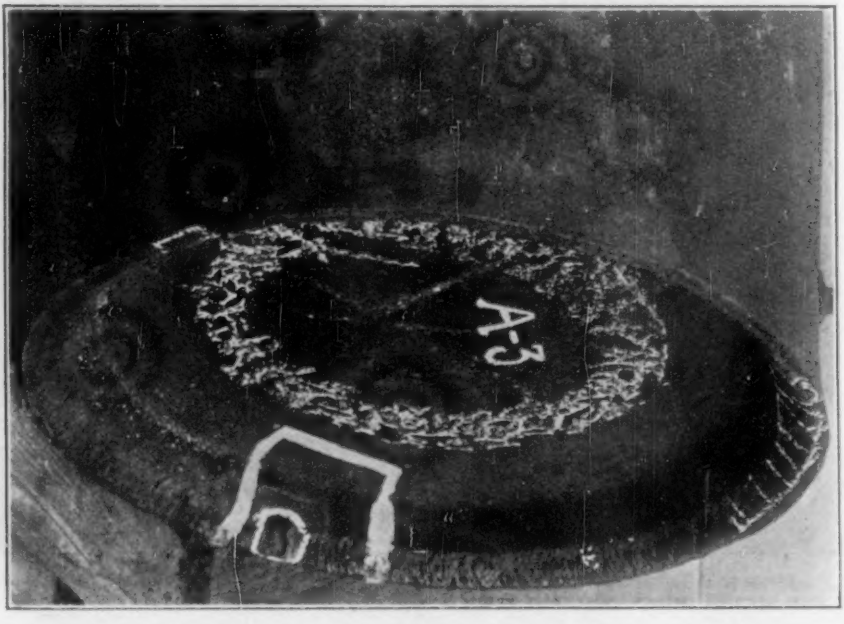


Figure 12. A close-up view of above. Portion of head outlined by white paint partially reversed. Crack in weld clearly indicated.

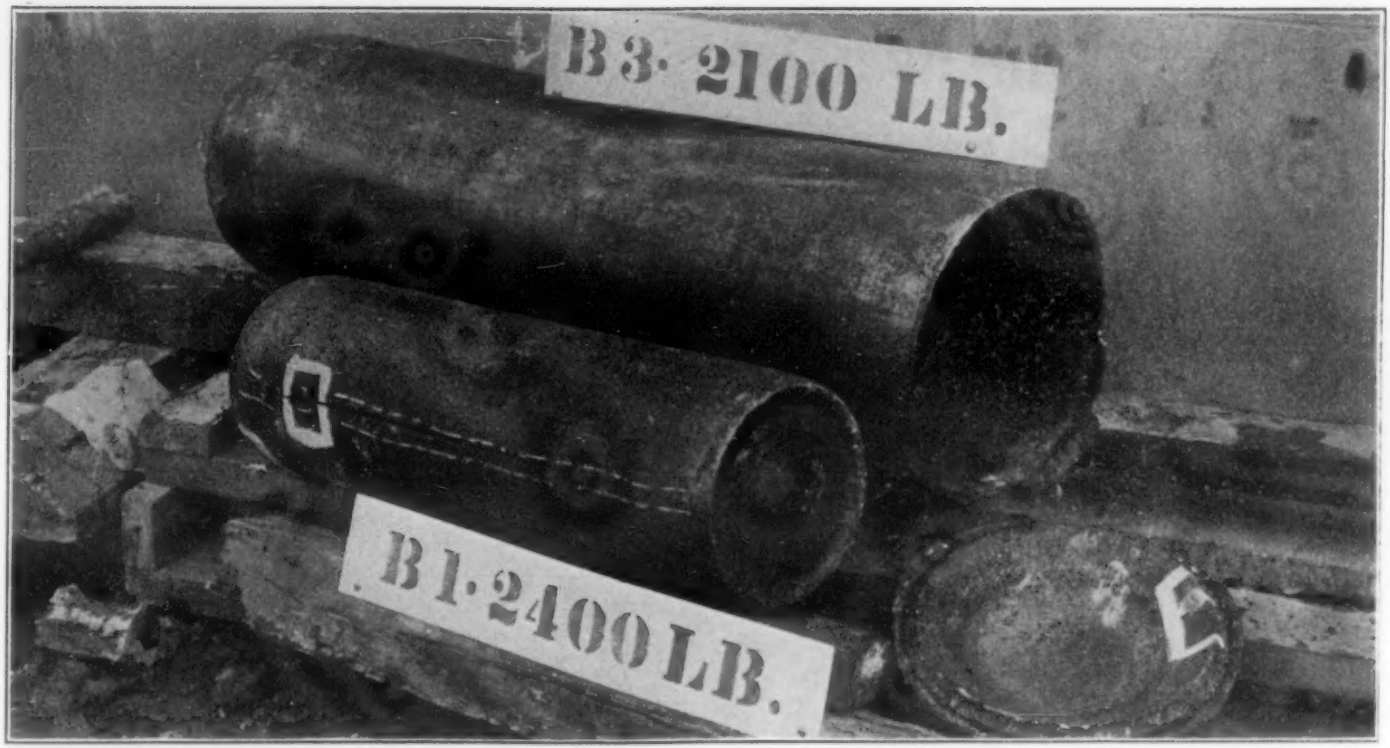


Figure 13. Tank B-1 shows longitudinal failure in shell, tank B-3 head failure by rupture of shell material close to head weld.

Figure 14. Longitudinal failure.

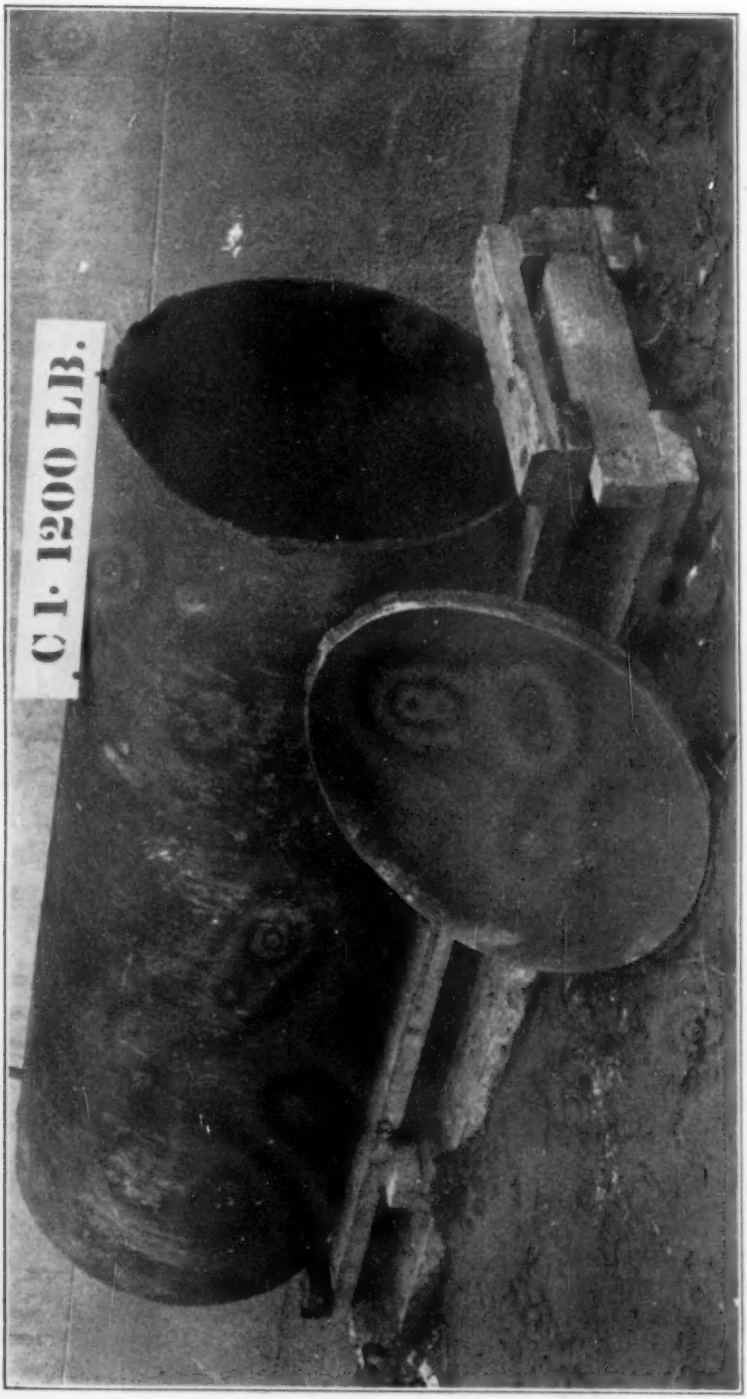


Figure 15. Head failure starting at bottom of weld where material was incompletely fused.

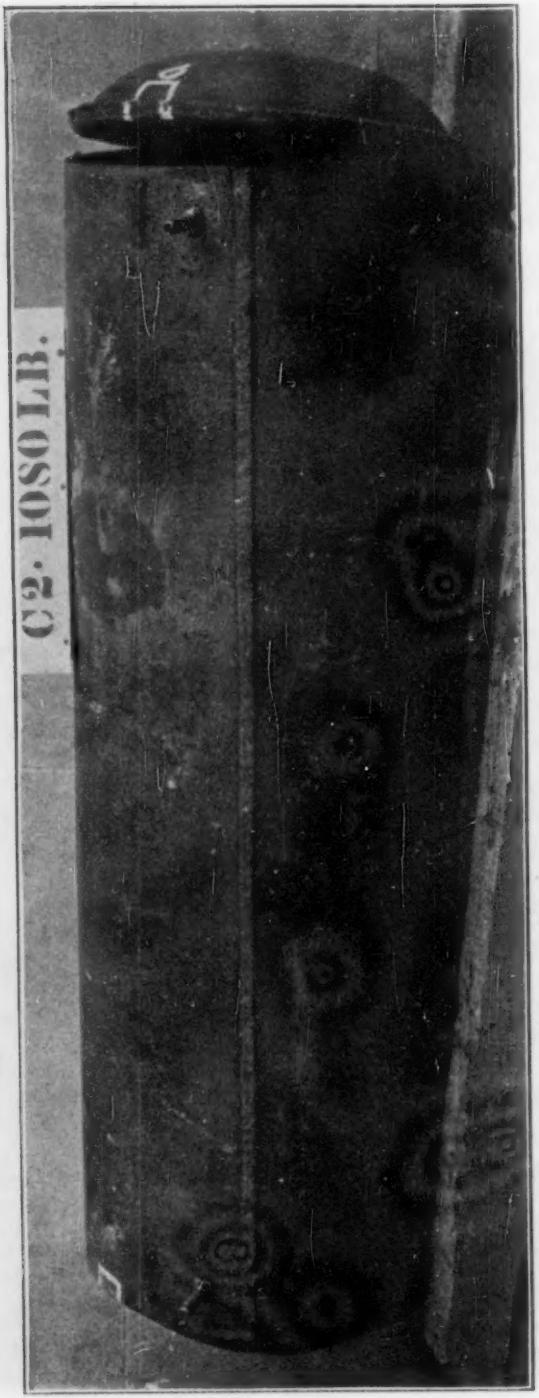


Figure 16. Head failure starting at bottom of weld where material was incompletely fused.

Figure 17. This figure shows in detail the incomplete fusion at bottom of weld of the "C" tanks which failed in head.

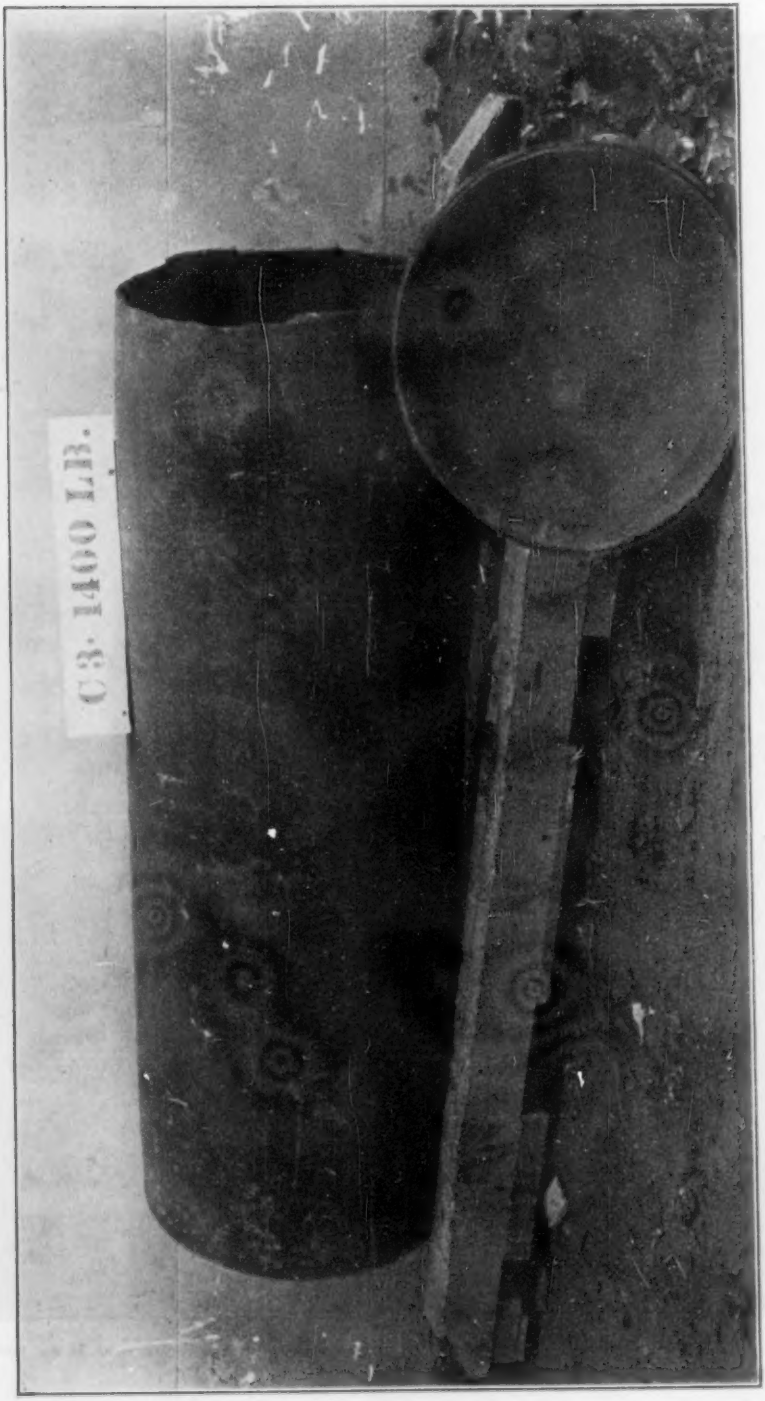


Figure 18. Head Failure.

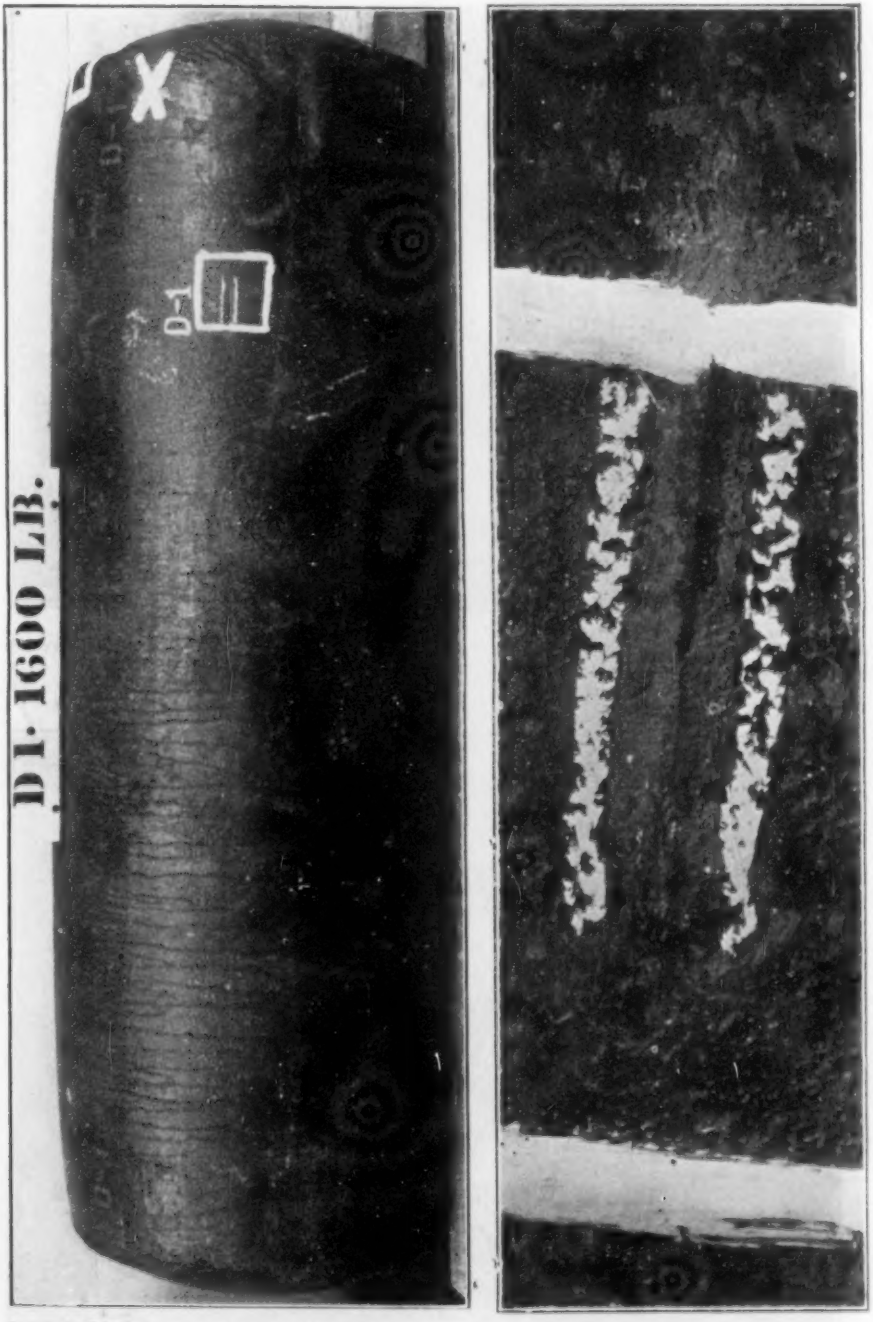


Figure 19. (left hand—Tank D-1). Failure by short longitudinal crack in shell.

Figure 20. (right hand) Close-up view of failure in Tank D-1.

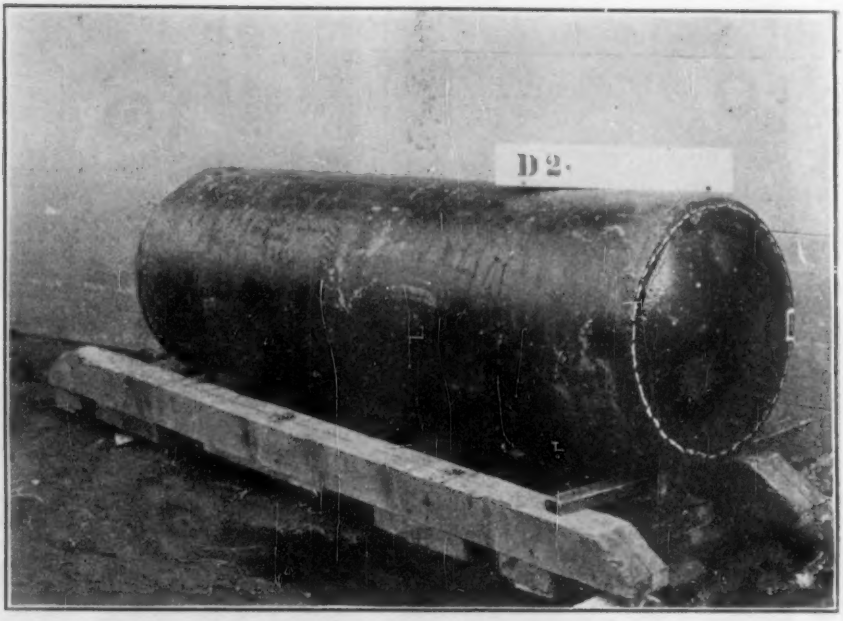


Figure 21. Head failure by continuous crack throughout head welds. Pressure at failure not accurately known because of freezing of gage line.

Figure 22. Head failure apparently due to thin shell.

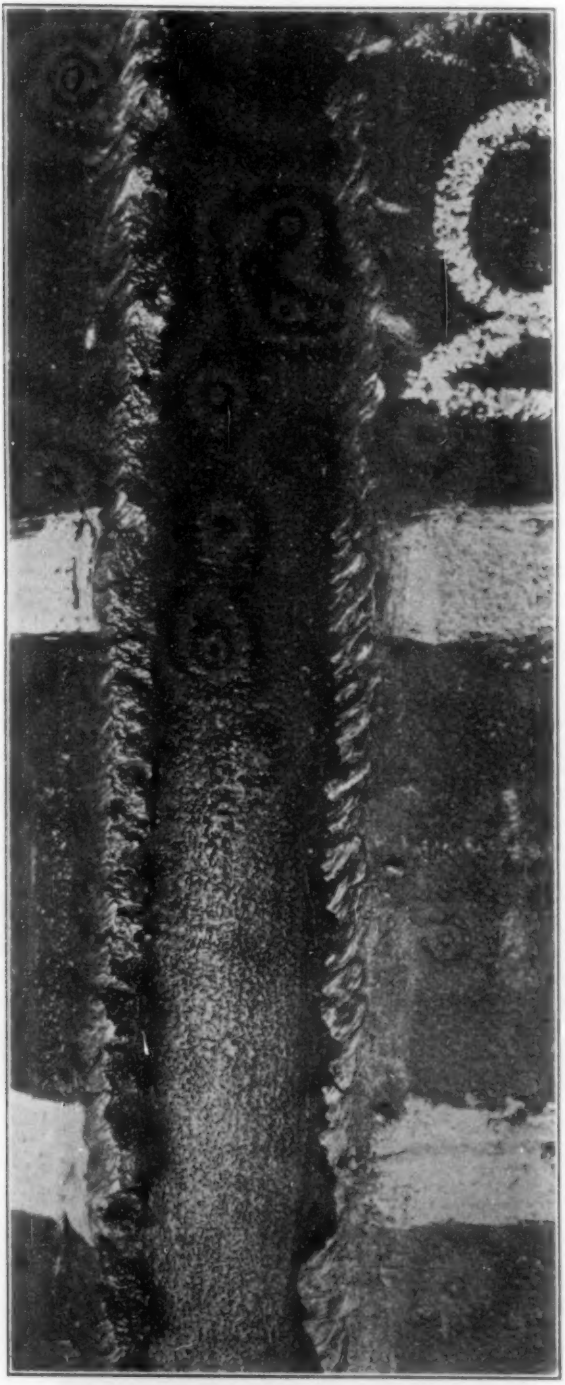


Figure 23. Close-up view of failure of Tank D-3.

Figure 24. Characteristic failure of single Vee longitudinal welds. In practically all cases single Vee welds failed primarily in the center of the weld. In some cases, however, part of the break lay outside of the weld.

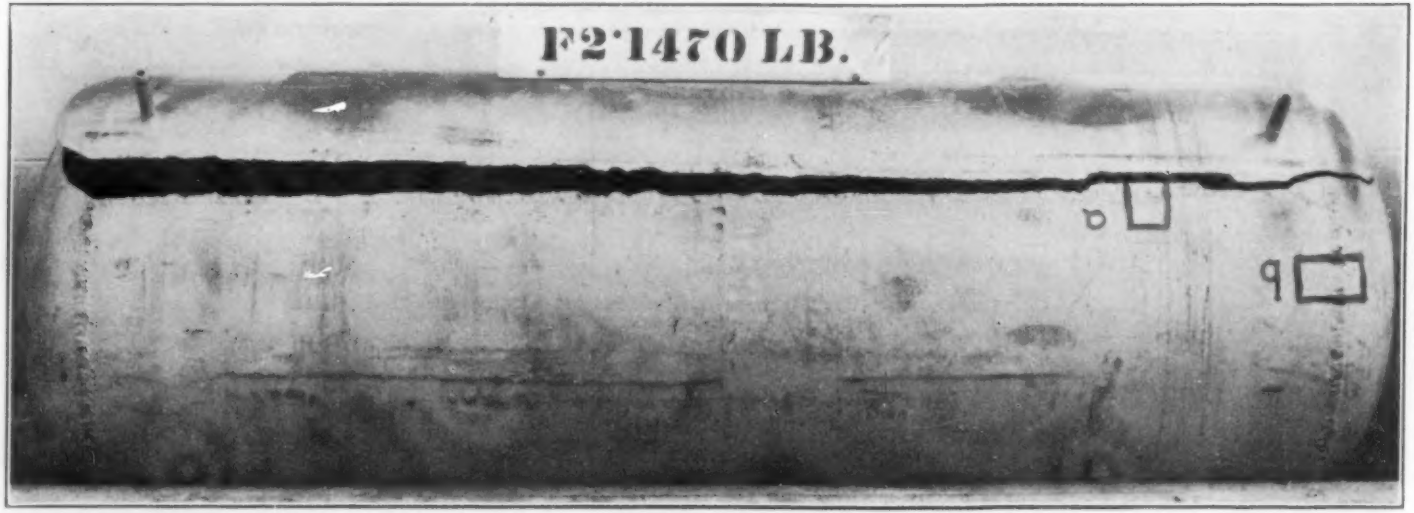


Figure 25. Characteristic failure of single Vee longitudinal welds. Failure occurred primarily in the center of the weld although part of the break lay just outside of the weld. Note extension of shell failure into head.

Figure 26. Close-up view of failure in Tank F-2 illustrates clearly that part of the break lay just outside of the weld.

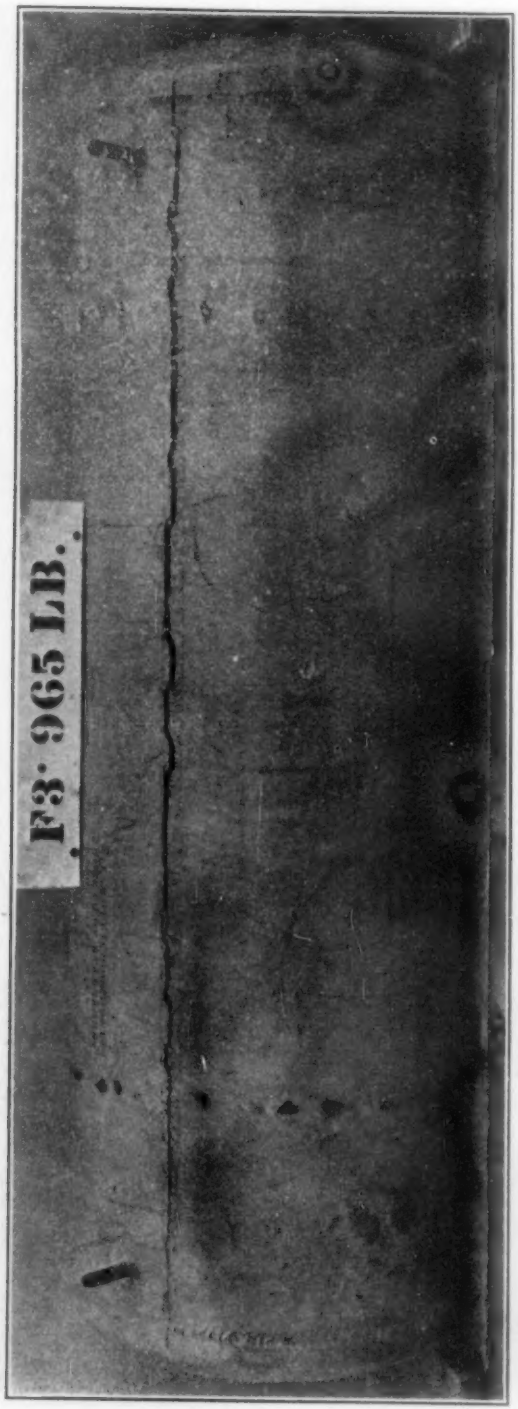


Figure 22. Another illustration of a failure of single Vee longitudinal weld in center of weld. Shell failure extended into head.

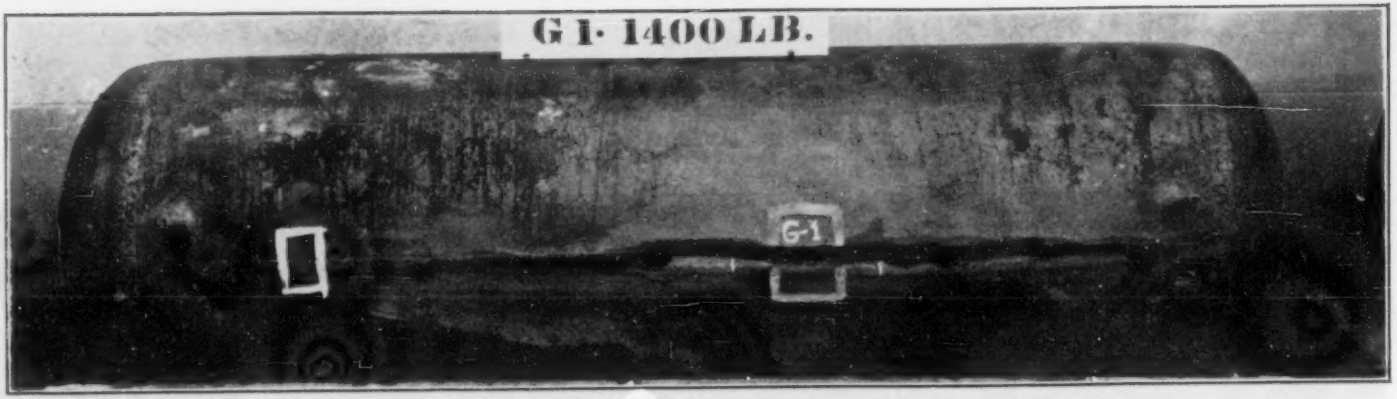


Figure 28. (upper figure). Typical failure of double Vee longitudinal welds. Failure largely along side of weld frequently crossing from side to side and sometimes partially in center of weld.

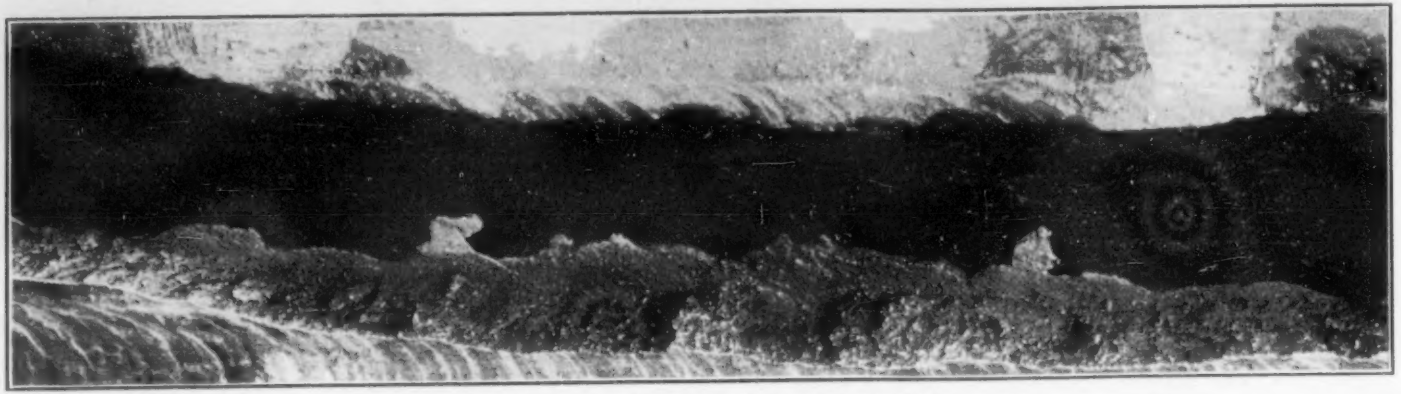


Figure 29. (lower figure). Close-up view of a failure in Tank G-1.

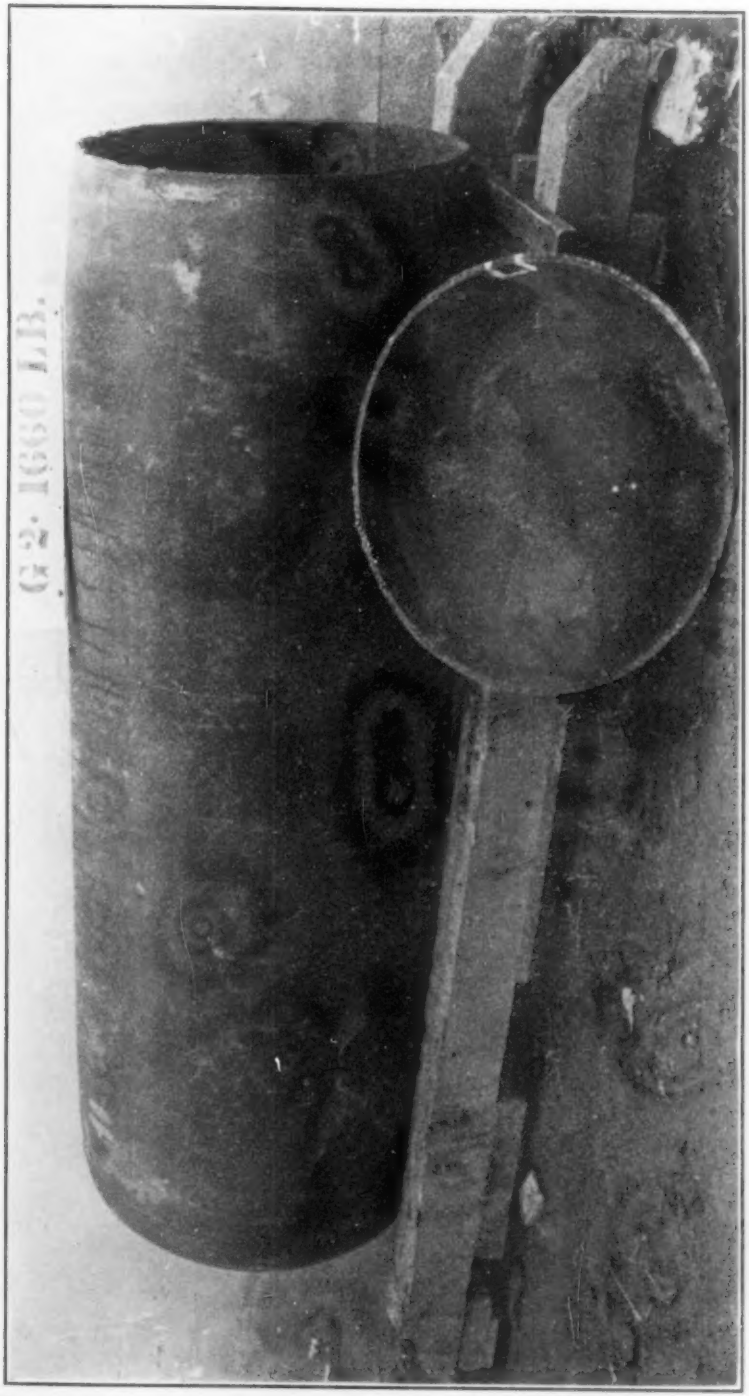


Figure 30. Head failure of G-2 at high pressure. Note large deformation of shell.

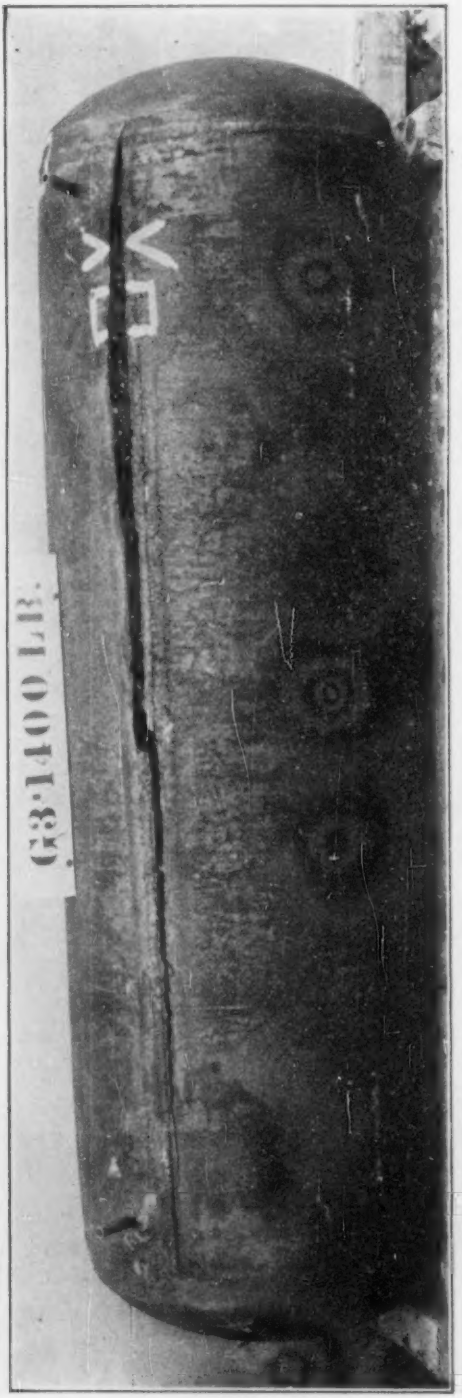
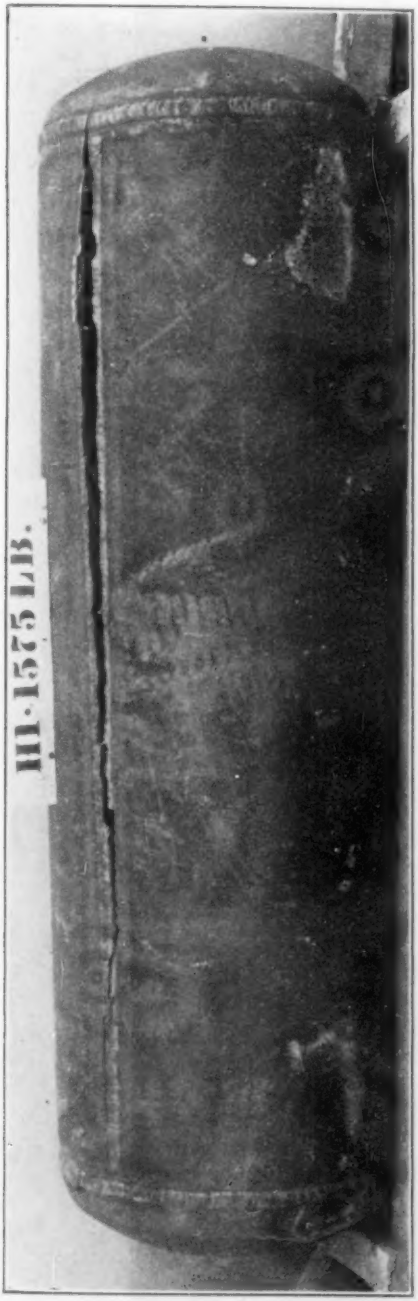


Figure 31. Typical failure of double Vee longitudinal welds. Failure along side of weld frequently crossing from side to side.



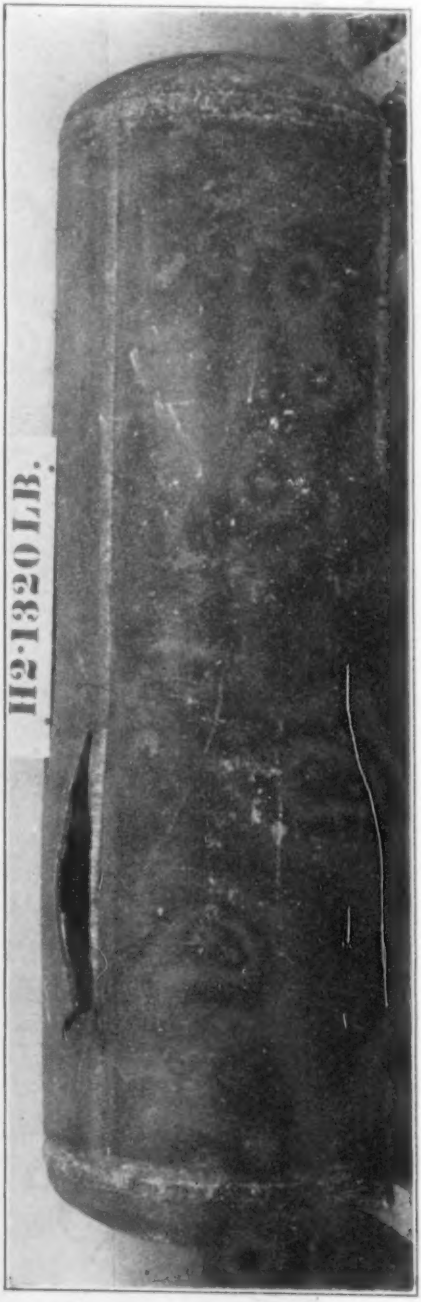


Figure 32. (left hand figure—Tank H-1) Failure of single Vee longitudinal weld.

Figure 33 (right hand tank H-2). Failure of single Vee longitudinal weld.

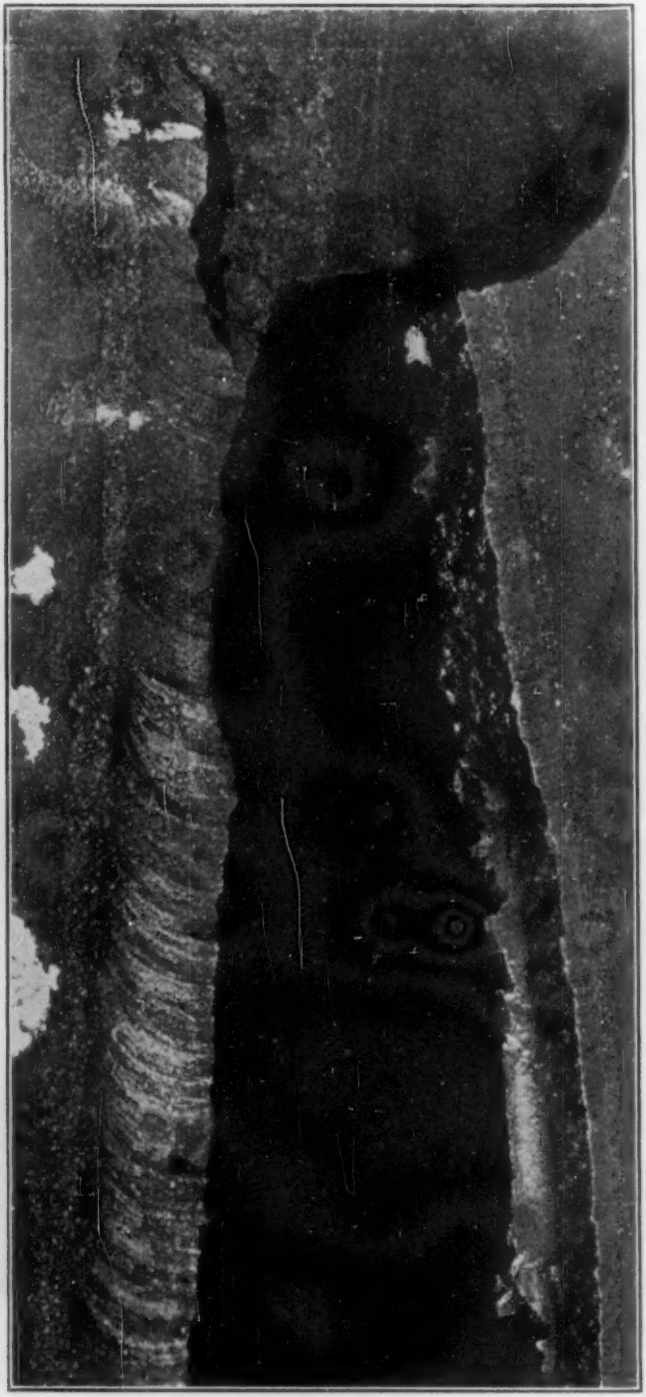


Figure 34. Close-up view of failure on Tank H-2 shown in figure 33.

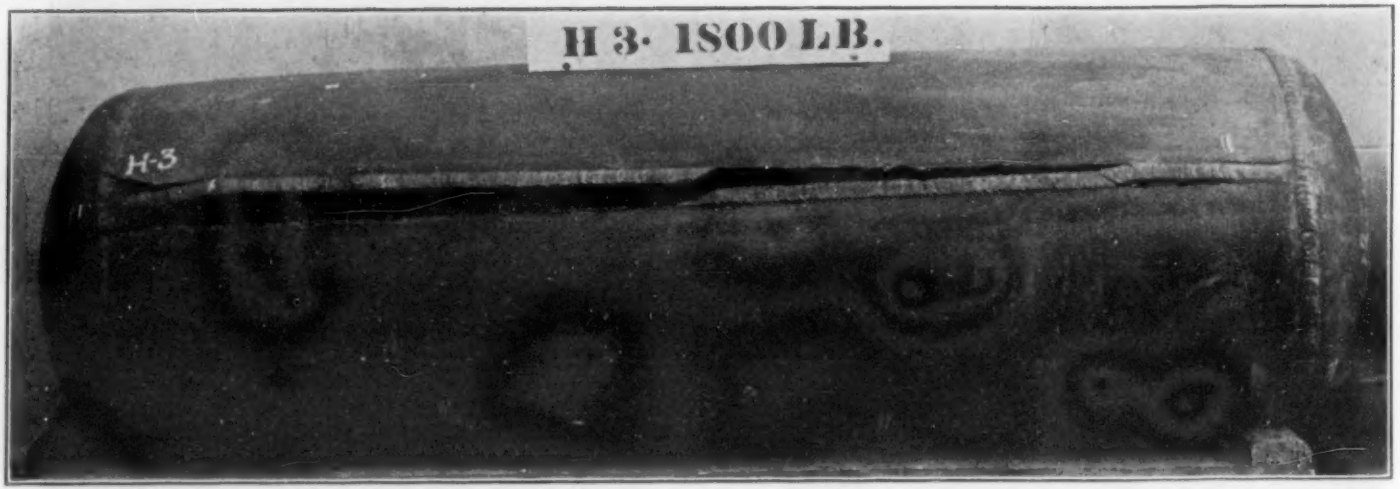


Figure 35. Double Vee longitudinal weld. Note typical difference in crack of weld failure and high pressure at which double Vee weld failed.

Figure 36. Close-up view of failure in Tank H-3 shown in Figure 35.

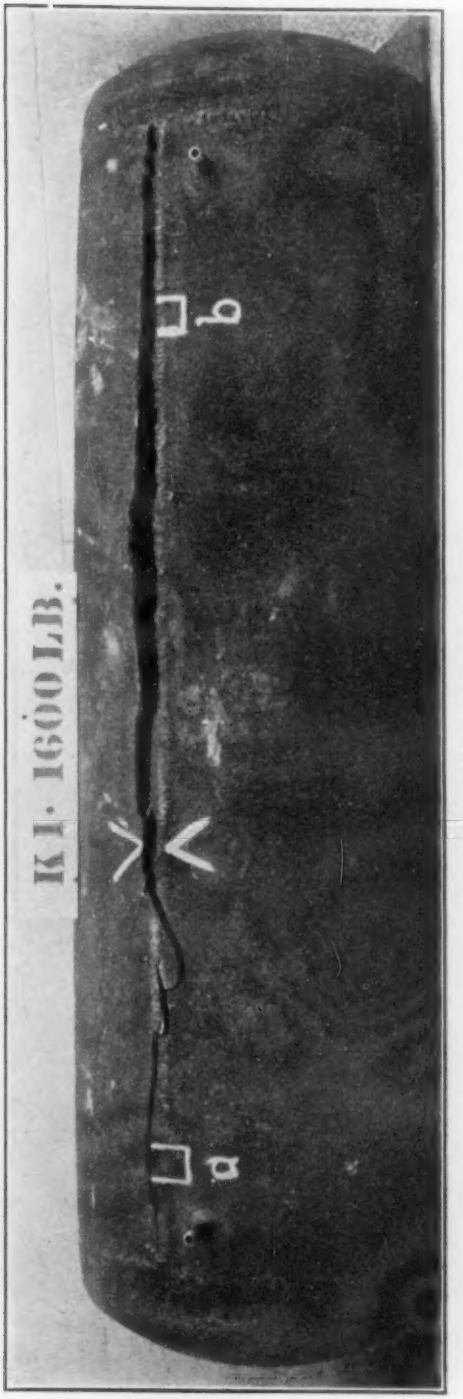


Figure 37. Typical failure of double Vee welds.

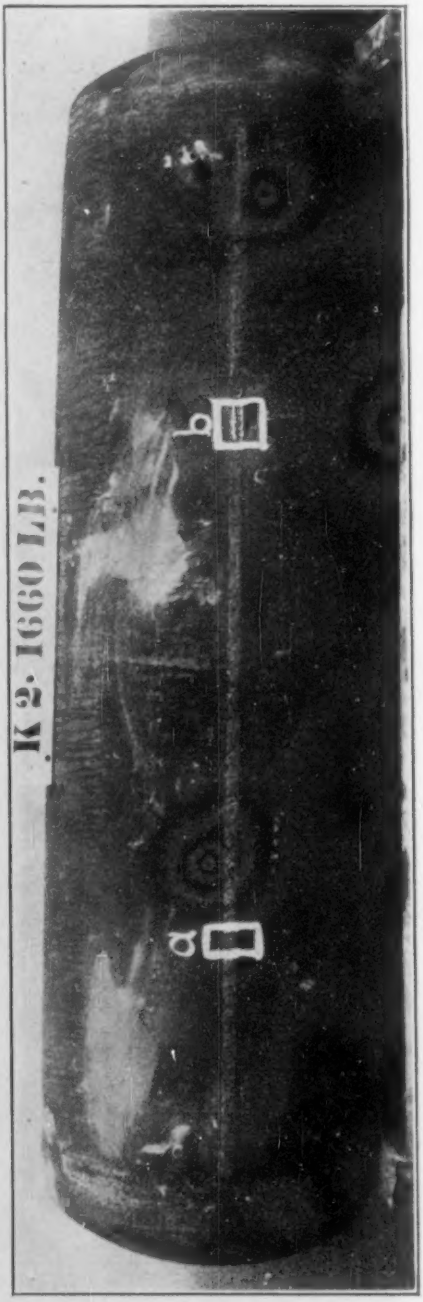
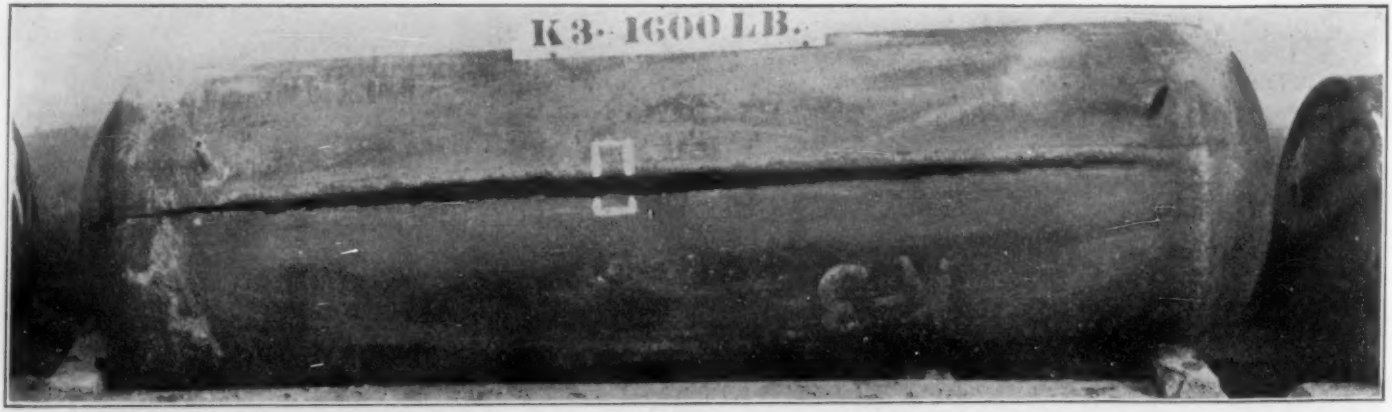


Figure 38. (left hand figure) Close up view of Tank K-1 shown in Figure 37.

Figure 39. (right hand figure). Failure at b due to small local defect. Could be repaired under Code.



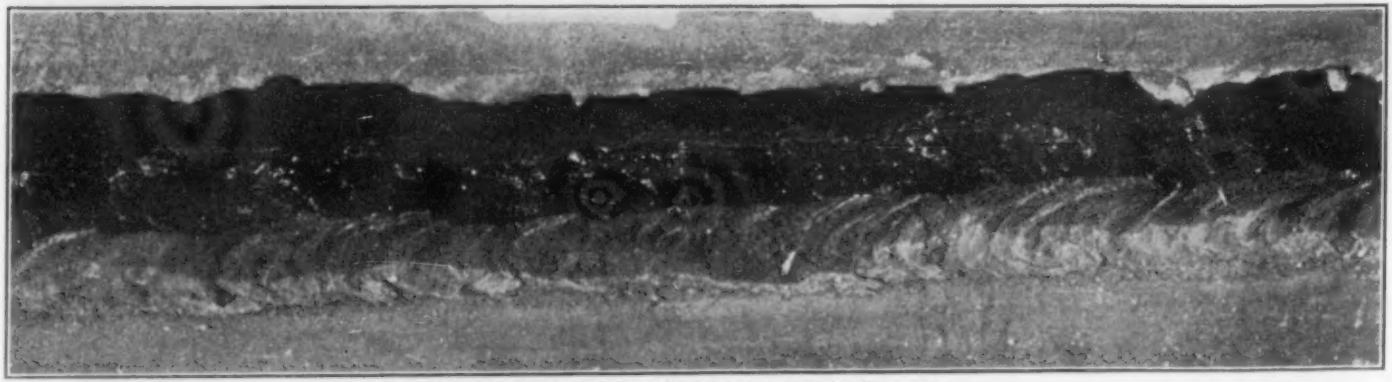


Figure 40. (upper—Tank K-3). Typical failure of double Vee weld.
Figure 41. (lower). Close-up view of above.

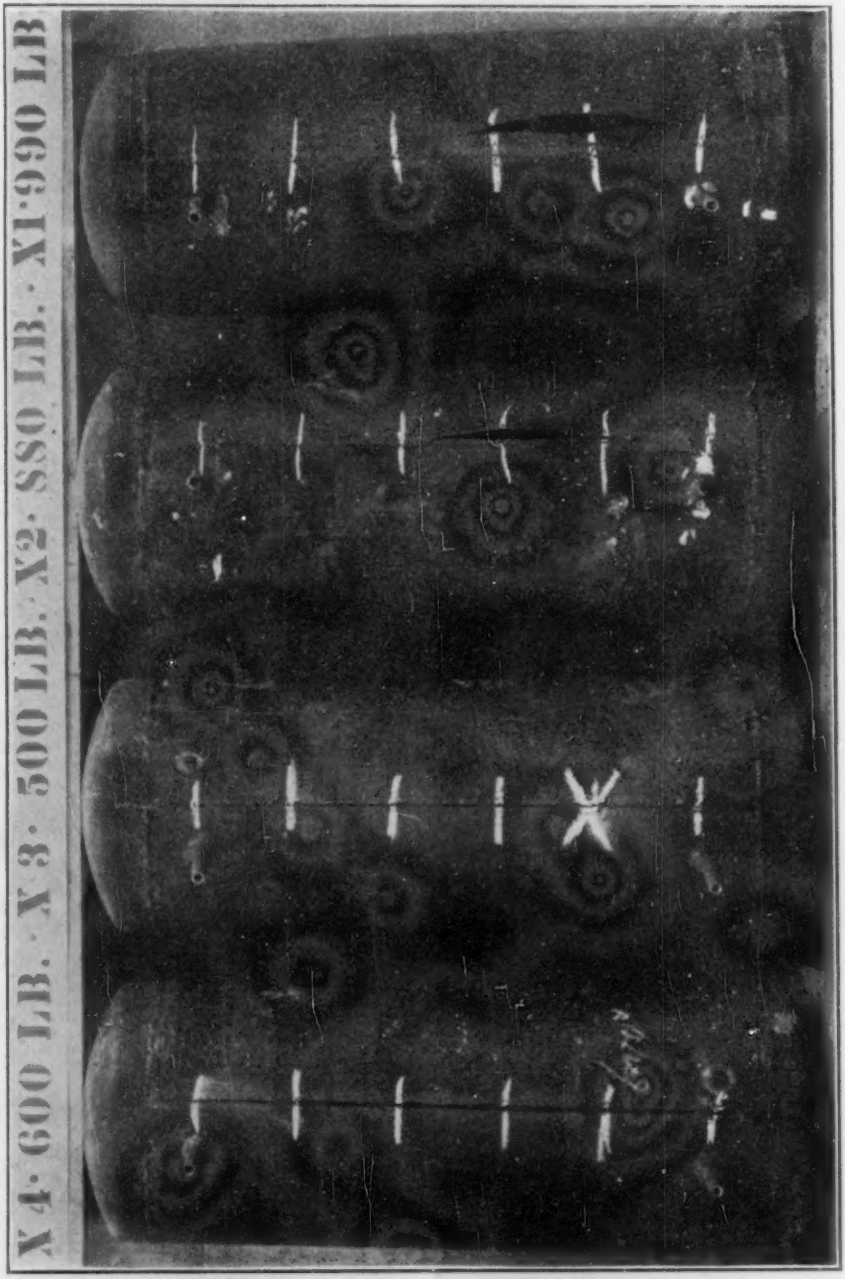


Figure 42. Special Tanks of 10 gage sheet, purposely welded "good" (X-1), "fair" (X-2), "poor" (X-3), and "bad" (X-4). See figure 2. These ruptures are typical of these different grades of welding.

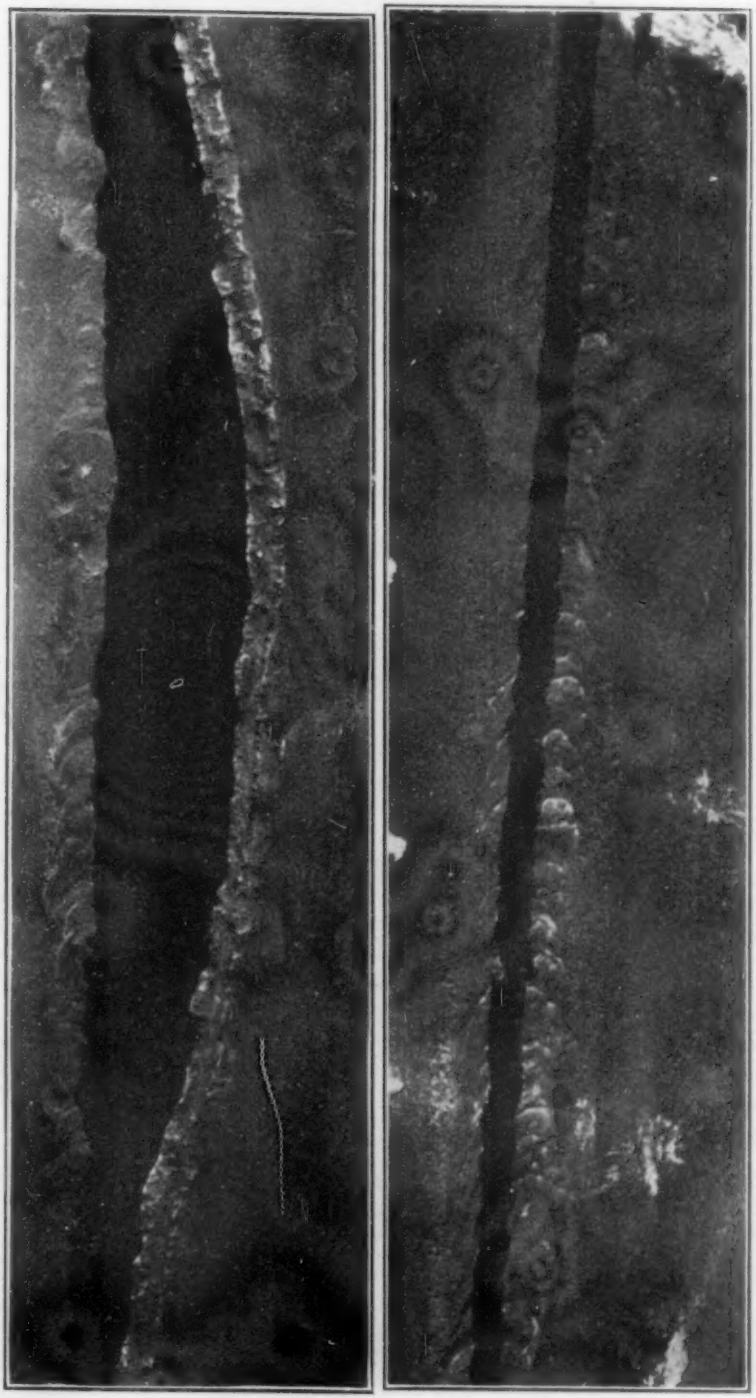


Figure 43. Upper figure is a close-up view of Tank X-2, and shows the unfused portion of the center of the "fair" weld.
Figure 44. Lower figure is a close-up view of Tank X-4 and shows the break in center of the "bad" single Vee weld.

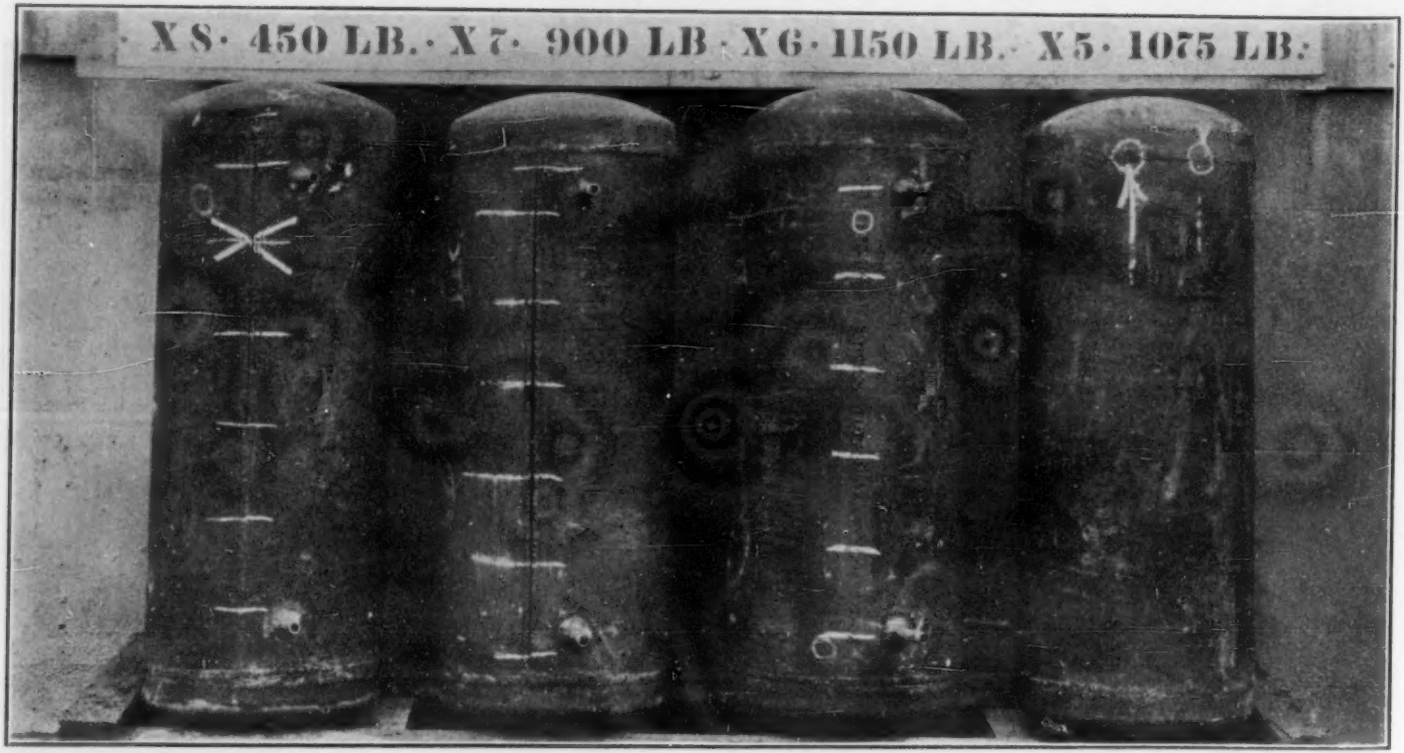


Figure 45. Special Tanks of 3-16 inch material. Concerning X-5, the manufacturer gives the following statement: "The workman who welded this Tank is an electric welder and had not received more than the equivalent of a day's instruction in gas welding when he fabricated this tank."

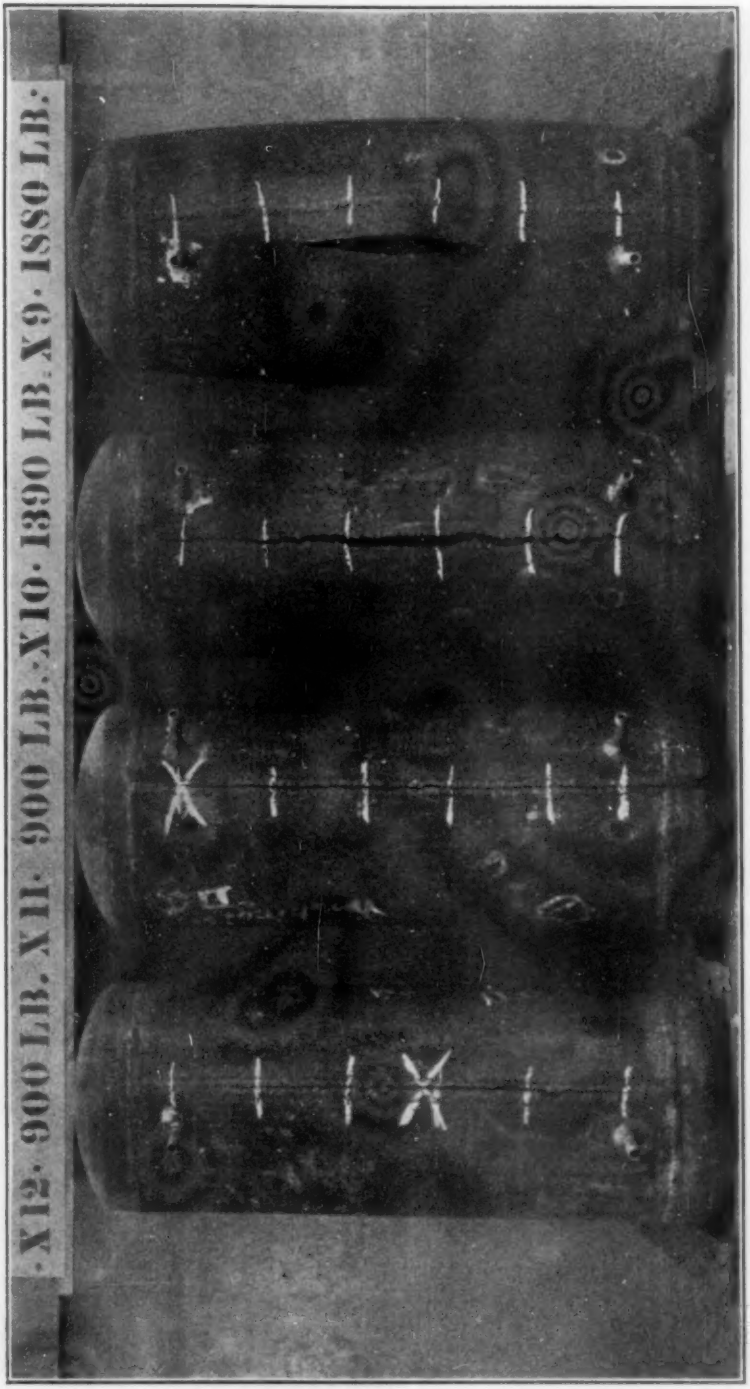


Figure 46. These Tanks made of 1/4 inch material show typical breaks for the different grades of welding; "good", "fair", "poor", and "bad".

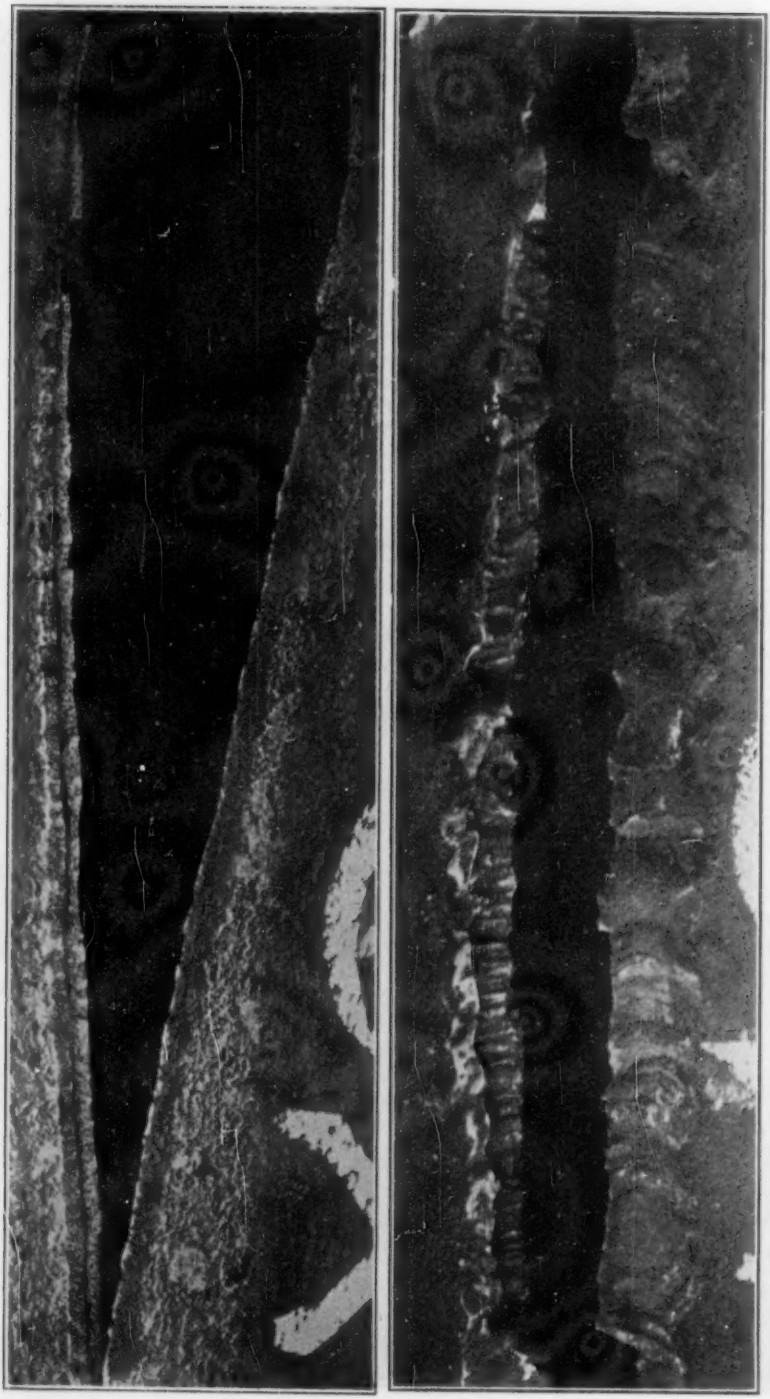


Figure 47. Upper figure shows a close-up view of Tank X-9 and illustrates "good" welding.
Figure 48. Lower figure shows a close-up view of break in Tank X-10 and illustrates "fair" welding.

Figure 49. Upper photograph shows a close-up view of Tank X-12 and illustrates "bad" welding.

Figure 50. Lower figure, Tank X-13 is a single Vee "fair" weld. (see figure 2), having a tacking strip as suggested by the Code. The manufacturer, however, adds the following comment: "The tacking, was too far apart and the strip thin; as a result, the strip warped."

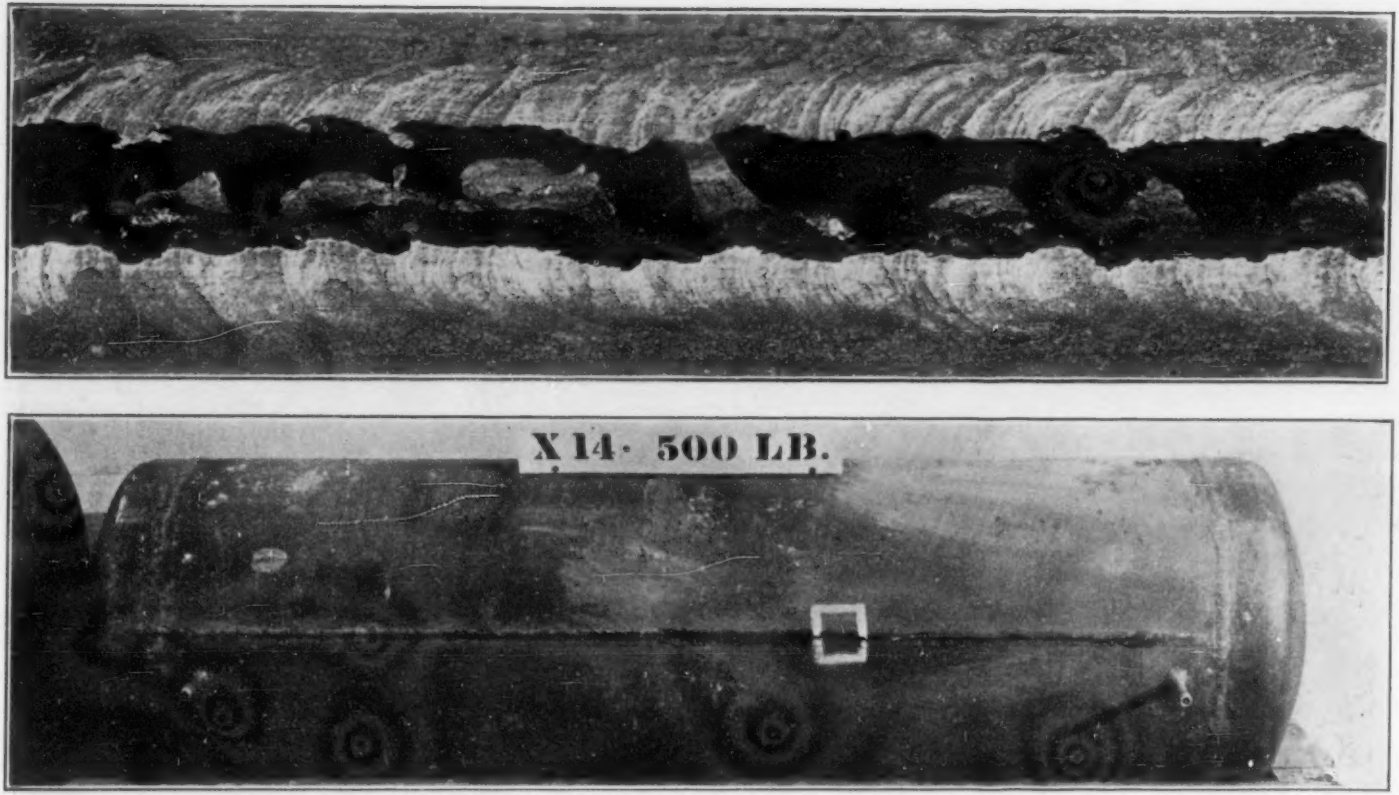


Figure 51. Upper figure shows a close-up view of break in Tank X-13 shown in Figure 50.
Figure 52. Lower figure shows Tank X-14.

Figure 53. Illustrates break in tank X-15.

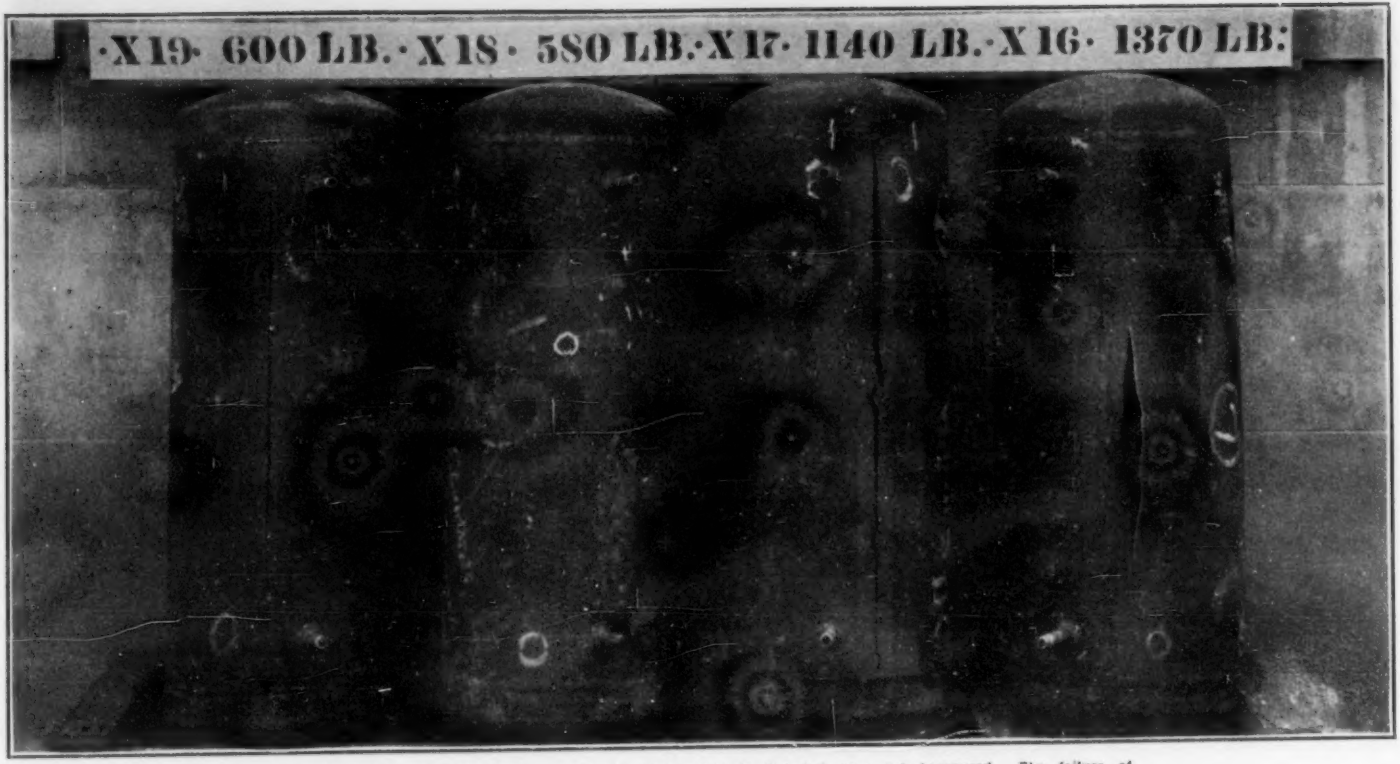


Figure 54. These Tanks correspond to Tanks X-5 to X-8 but were not hammered. The failure of X-16, X-17 and X-19 is the same as X-5, X-6 and X-8. (see figure 45). X-18 failed by local defect.

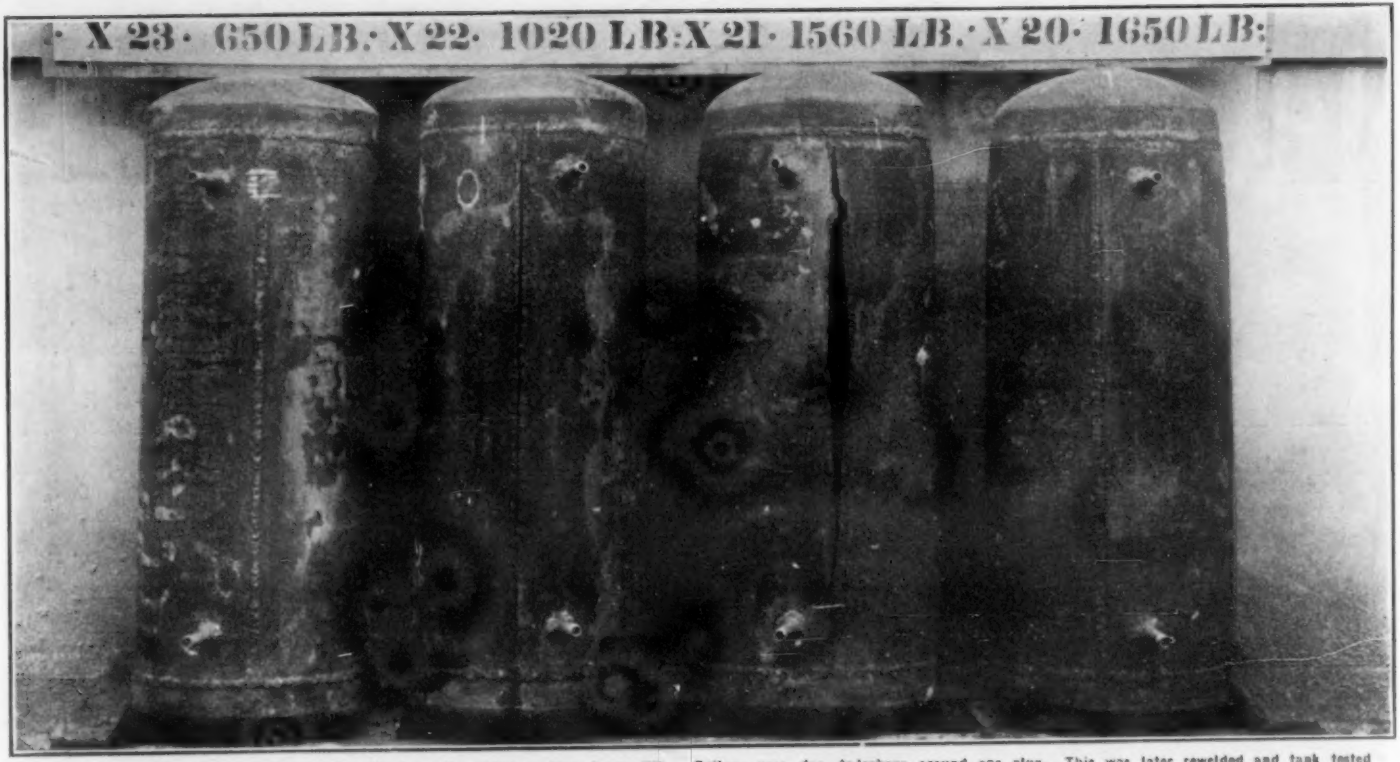


Figure 55. Tank X-20 was provided with inspection plugs. (see figure 56). Failure was due to leakage around one plug. This was later rewelded and tank tested to destruction. (see figure 60). In other respects these tanks correspond to tanks X-9 to X-12 but were not hammered. Failure of X-20, Figure 64, X-21 and X-22 correspond to failure of X-9, X-10 and X-11, X-23 failed by local defect.

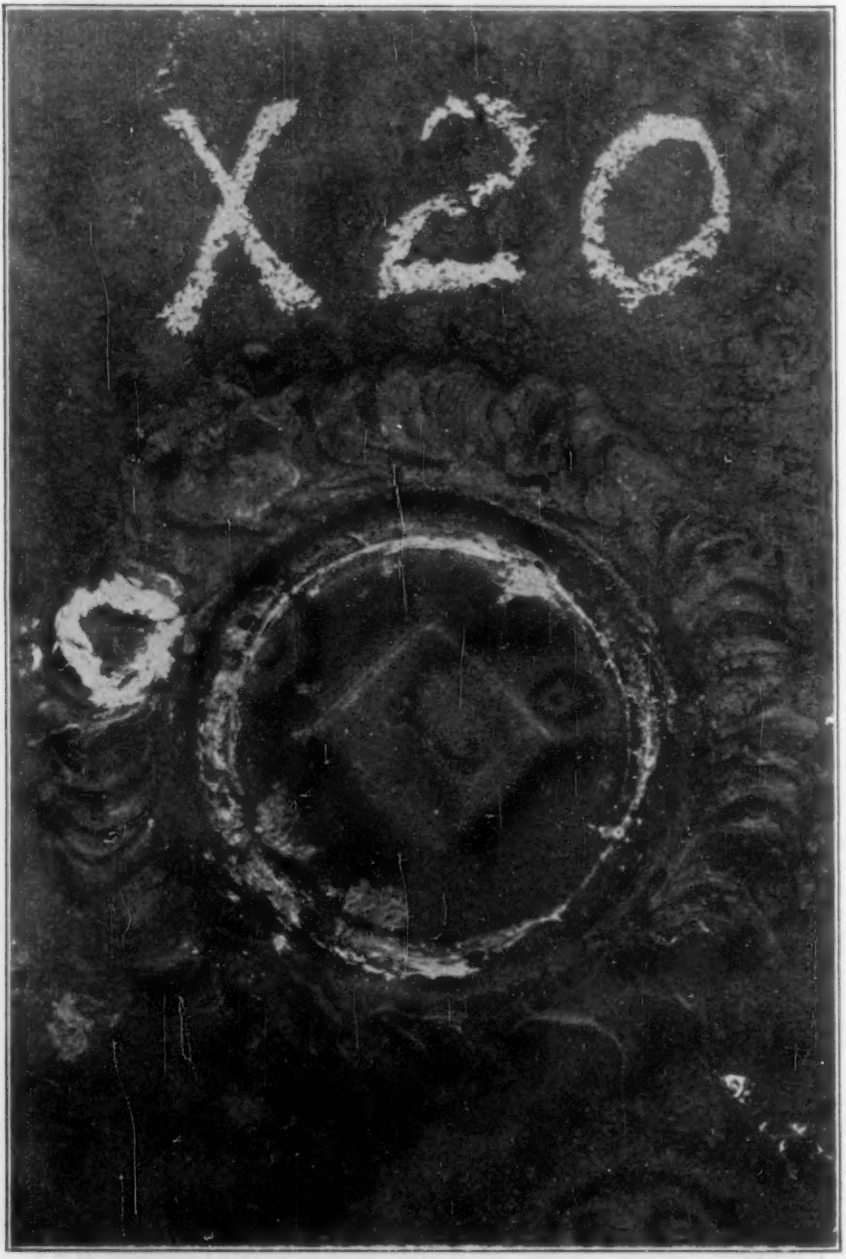


Figure 56. This shows a close-up view of the inspection plug in Tank X-20. Failure at pinhole in white circle at left.

Figure 57. Upper Figure illustrates a close-up view of the break in Tank X-21.
Figure 58. The lower photograph is a close-up view of the break in Tank X-22.

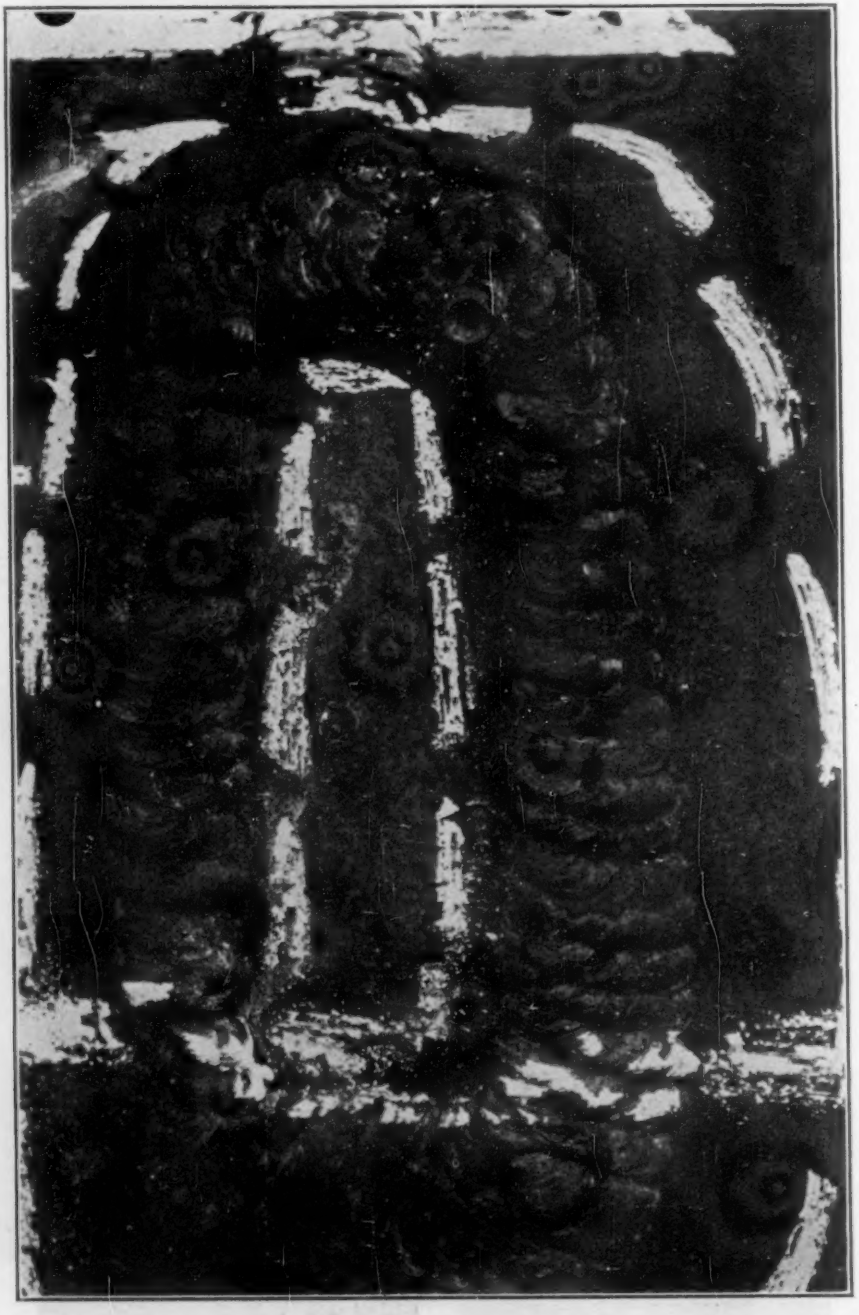
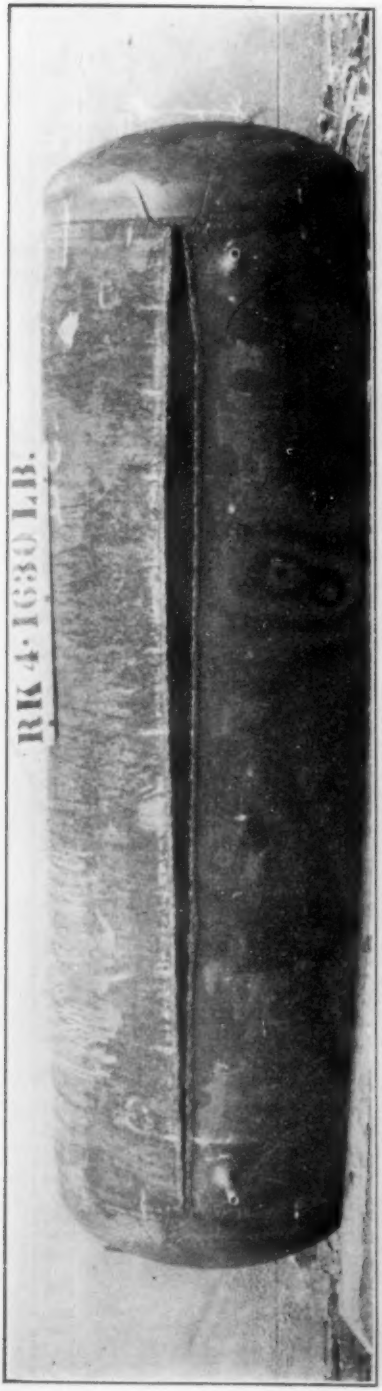


Figure 39. Close up view of repair in Tank K-4. This repair was made in accordance with the provisions of the "Code" for such repairs and tested to destruction.



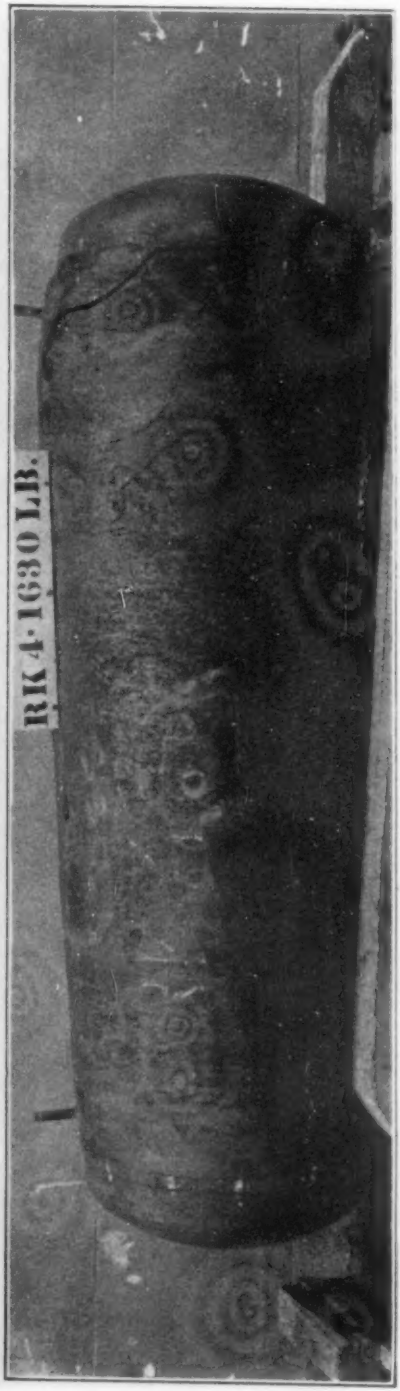


Figure 60. Upper figure shows result of test of Tank K-4 after it had been repaired in accordance with the provisions of the "Code."
Figure 61. The lower figure is another view of Tank K-4 and shows extension of the break.

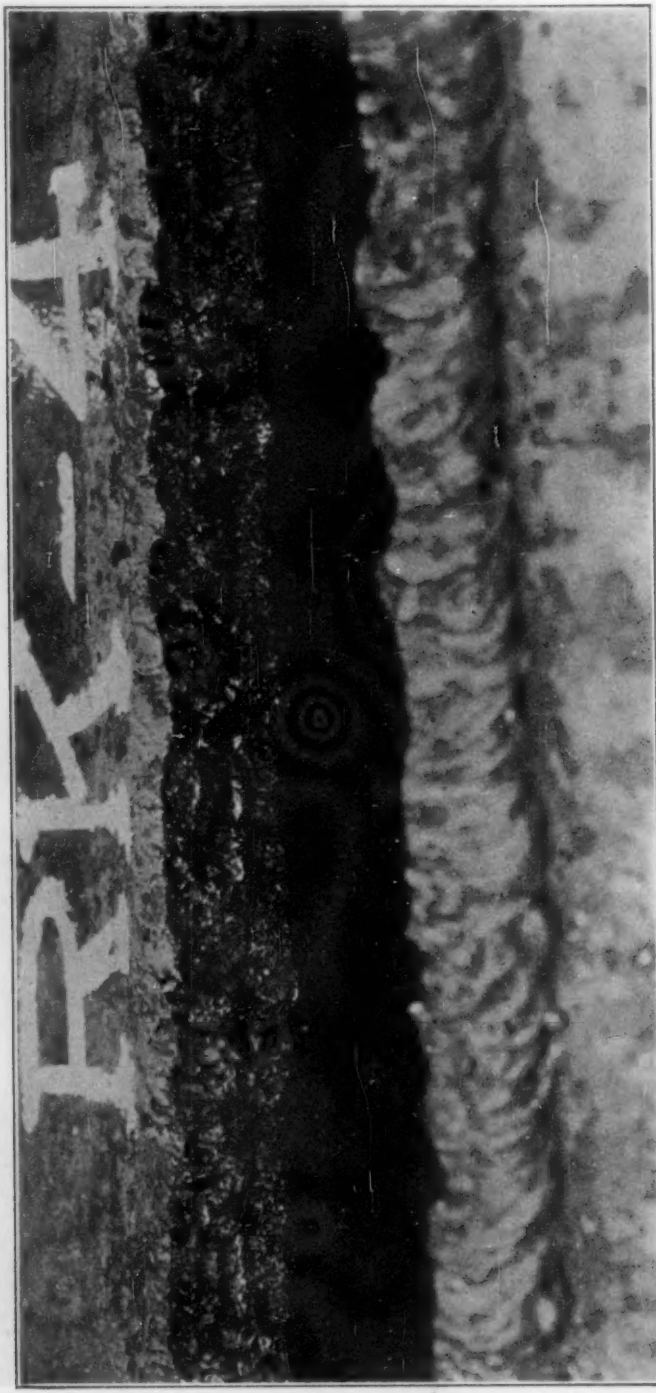


Figure 62. Close-up view of break in Tank K-4 after it had been repaired

Figure 63. Rewelded Tanks. These Tanks were repaired as authorized by the "Code". The failures of RX-6, RX-18 and RX-19 are typical "good" welds. See figures 2, 42, 46 and 54. The X-5 failed by a local defect in the head weld.

Figure 64. This shows a test of Tank X-20 after the end plug was repaired and final failure is typical of "good" welds.

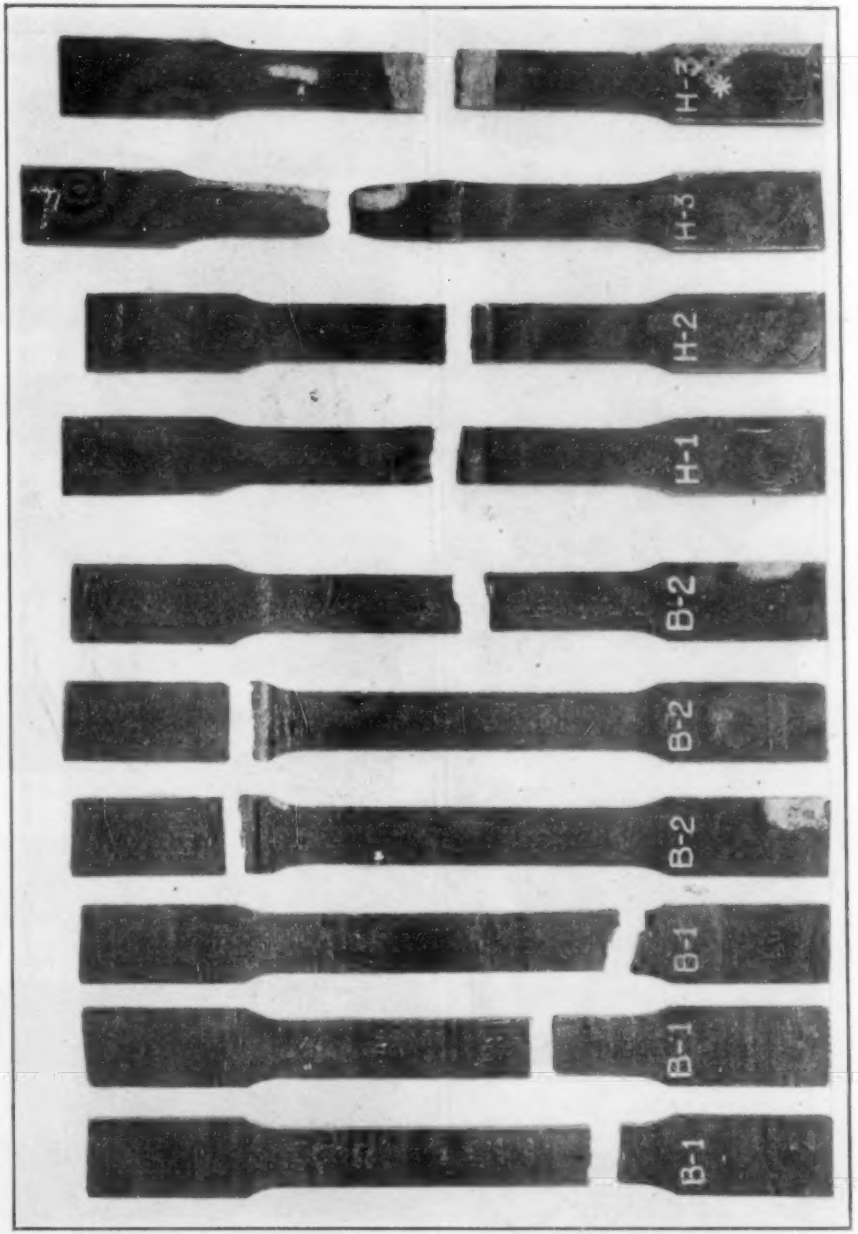


Figure 65. Test specimens. The specimens marked B-1 and B-2 were cut circumferentially from pipe of small diameter and straightened for test. They may therefore have been weakened by excessive bending. The failures in two of the B-2 specimens are apparently through the longitudinal weld of the pipe. It may be noted that except for one "fair" weld, all the double Vee welds tested broke outside the weld while all the single Vee welds tested broke at the weld. The second, H-3 was a double Vee weld machined flush with plate.

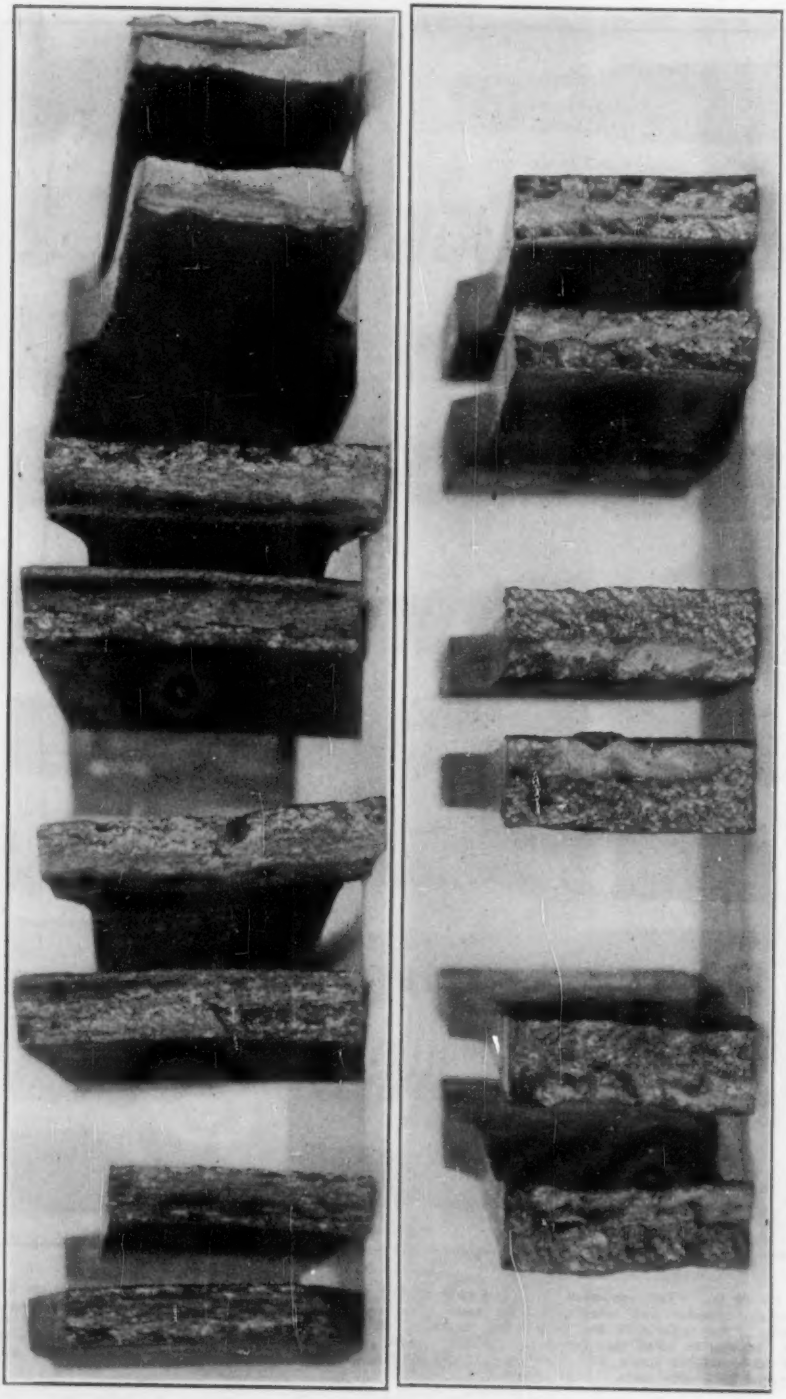


Figure 66. Upper figure from left to right shows broken ends of specimens B-1, B-2, B-2 and D-3 respectively.

Figure 67. Lower figure from left to right shows broken ends of specimens H-1, H-2 and H-3 respectively.

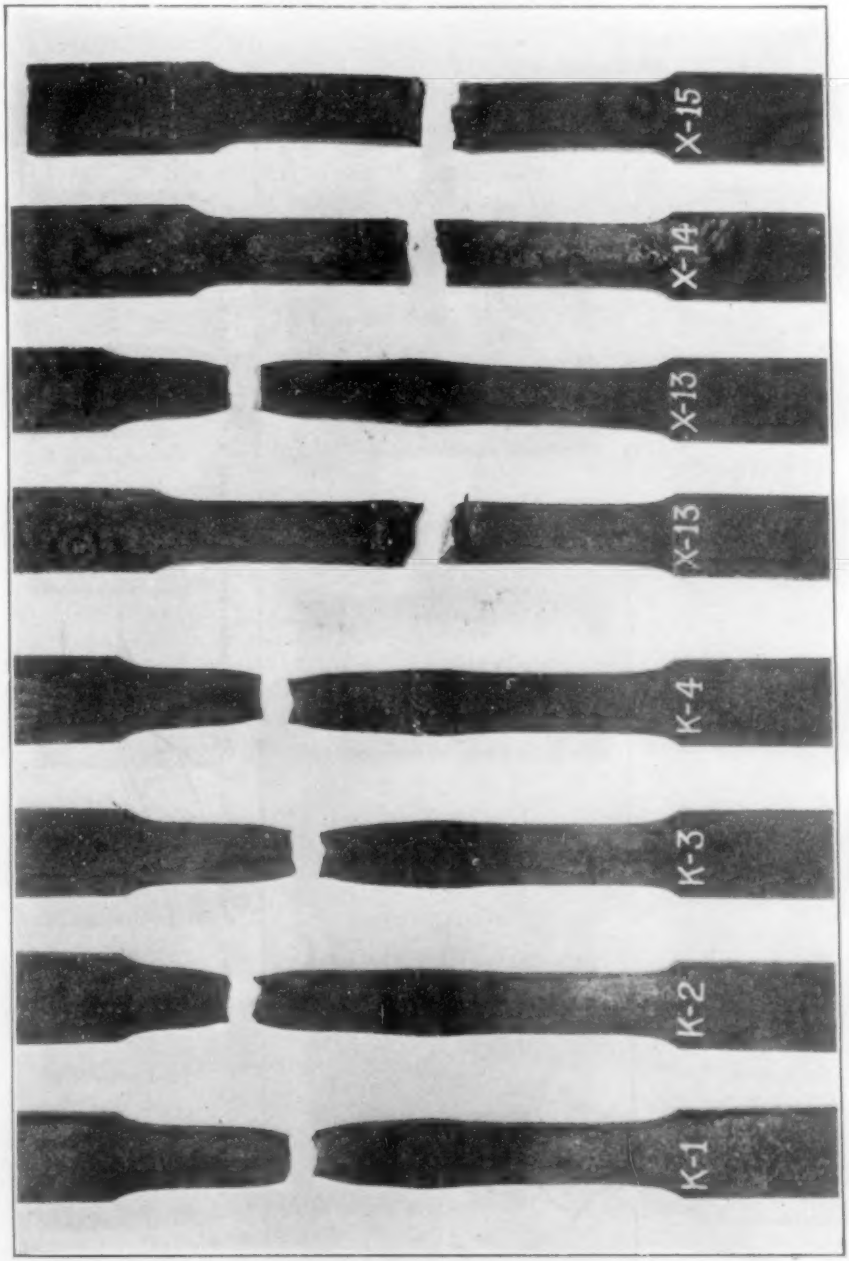


Figure 68. It may be noted that except for one "fair" weld, all double Vee welds tested broke outside the weld while all the single Vee welds tested broke at the weld.

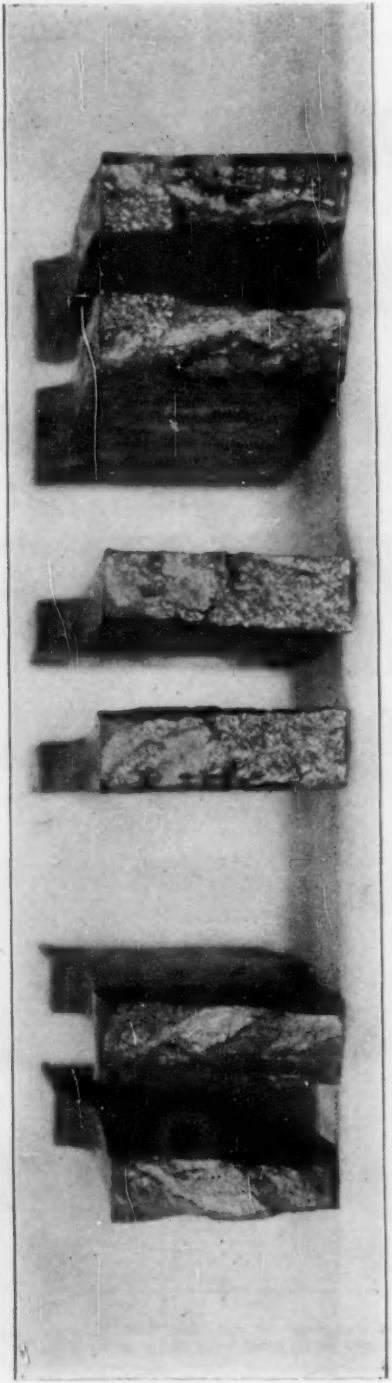


Figure 69. Figures from left to right show broken ends of specimens X-13, X-14 and X-15 respectively.

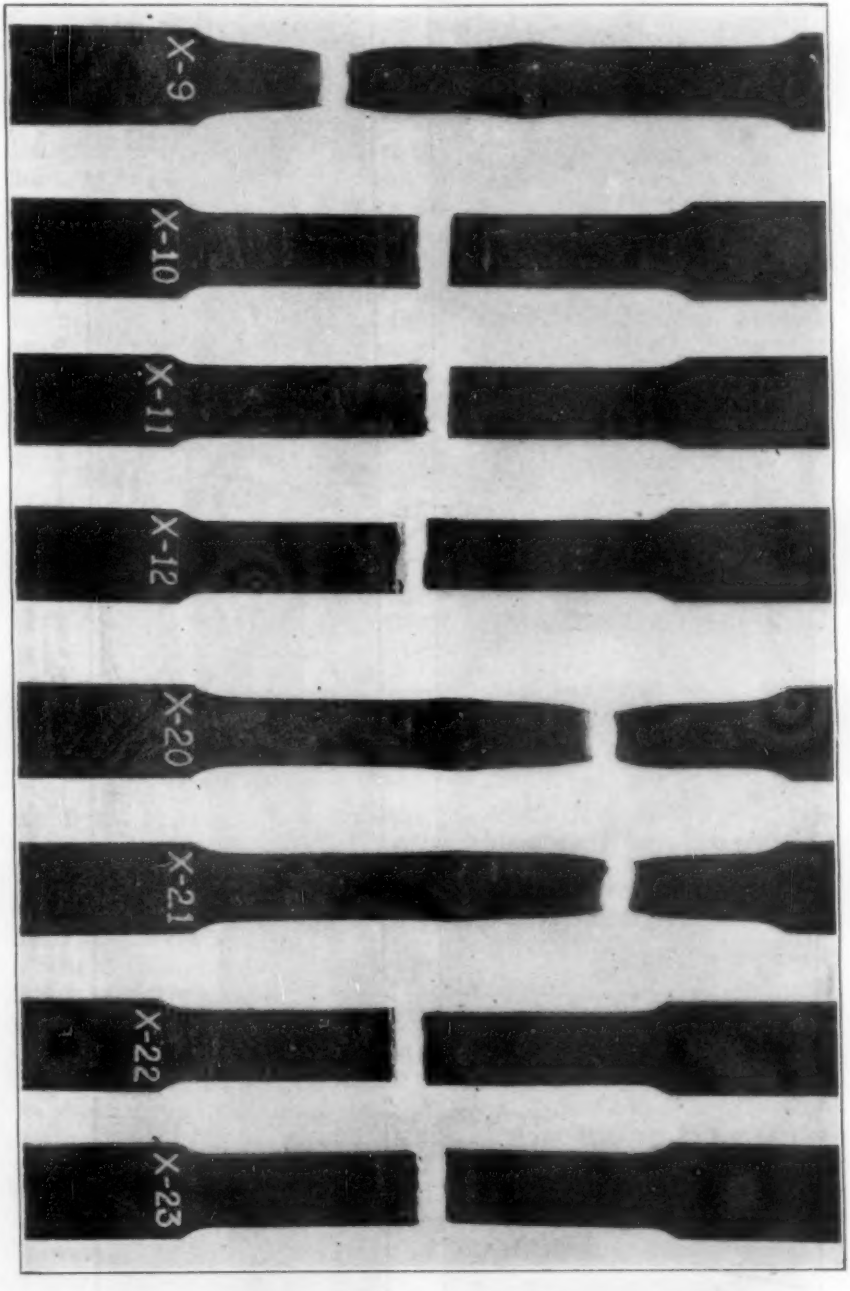
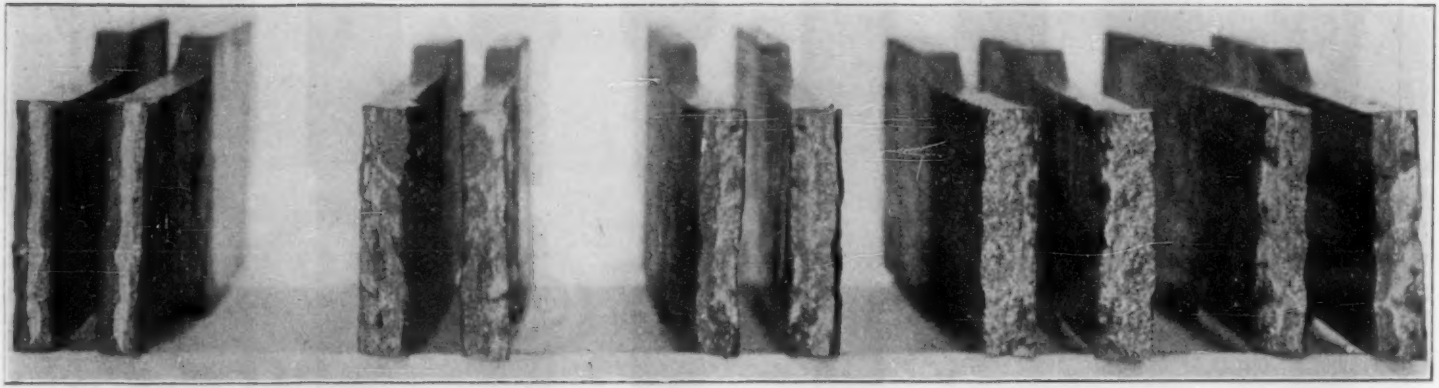


Figure 70. It may be noted that except for one "fair" weld all the double Vee welds tested broke outside the weld while all the single Vee welds tested broke at the weld.



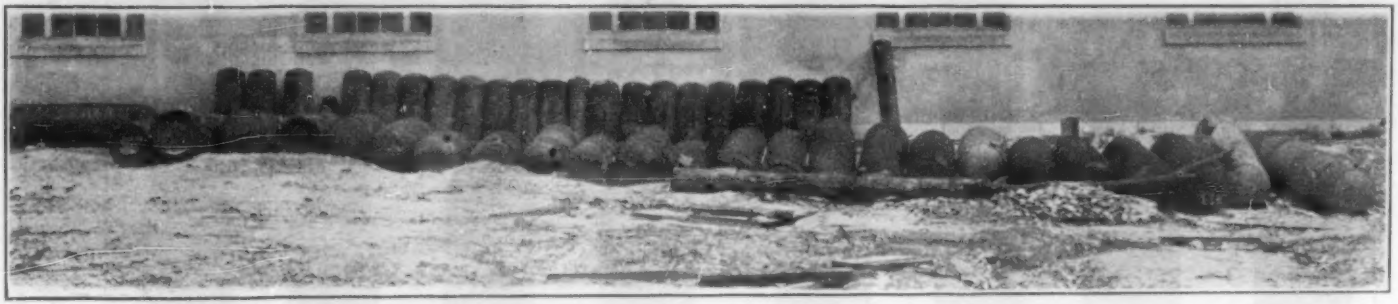


Figure 71. Upper figure from left to right shows the broken ends of specimens from Tanks X-10, X-11, X-12, X-22 and X-23 respectively.
Figure 72. Lower figure shows a general view of the tested tanks.

METALLOGRAPHIC EXAMINATION

1. *Purpose of Examination.*

The purpose of the examination was to supplement the data obtained in the mechanical tests by a study of the intrinsic quality of the welds, in so far as it is revealed by metallographic means, as distinguished from other factors that affect their strength, such as the type of the joint. In fusion welds, that is, oxy-acetylene and electric-arc, this quality may be considered to be determined to a large extent by the following factors:—1, the physical soundness of the metal of the fused-in portion; 2, the completeness of the bond between the fused-in metal and the joined plates; 3, the degree and extent of grain coarsening of the plate, produced by the welding heat. The first two of these may be judged by the appearance of the polished and etched sections through the welds, according to the prevalence or absence of blow-holes and inclusions in the fused-in

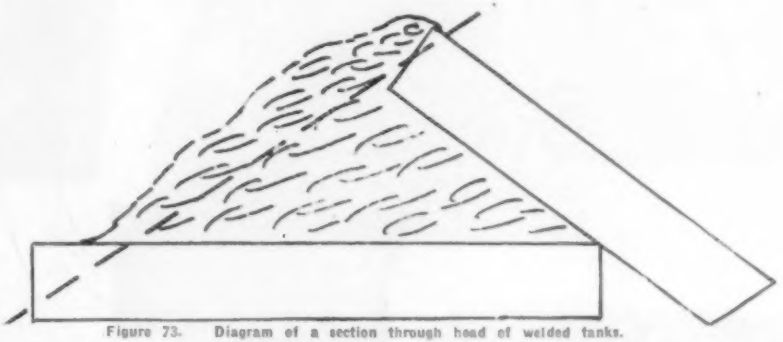


Figure 73. Diagram of a section through head of welded tanks.

metal and at its juncture with the plate; the third by the grain size of the plate near the weld. The quality and type (steel or wrought iron) of the plates may also be judged somewhat, by the number of inclusions and streaks in the material.

Macrostructure.

There follow, photographs, approximately natural size, of polished and of etched sections of the specimens chosen for examination after the testing of the tanks, as indicated in the photographs of the tested tanks. The designation under each of the following figures indicates the number of the tank and of the specimen used as shown in summary, p. 147. Wherever possible, a longitudinal section was obtained by planing off the outer surface of the welded area and a transverse section of the weld adjacent to this longitudinal section was used.

In the case of sections through the junction of the plate and head, however, the planed-off section of the weld was taken as shown in Figure 73.

In the photographs which follow, it will be readily apparent as to what sections were used in the examination. The etching reagent used was an aqueous solution of ammonium persulphate. After

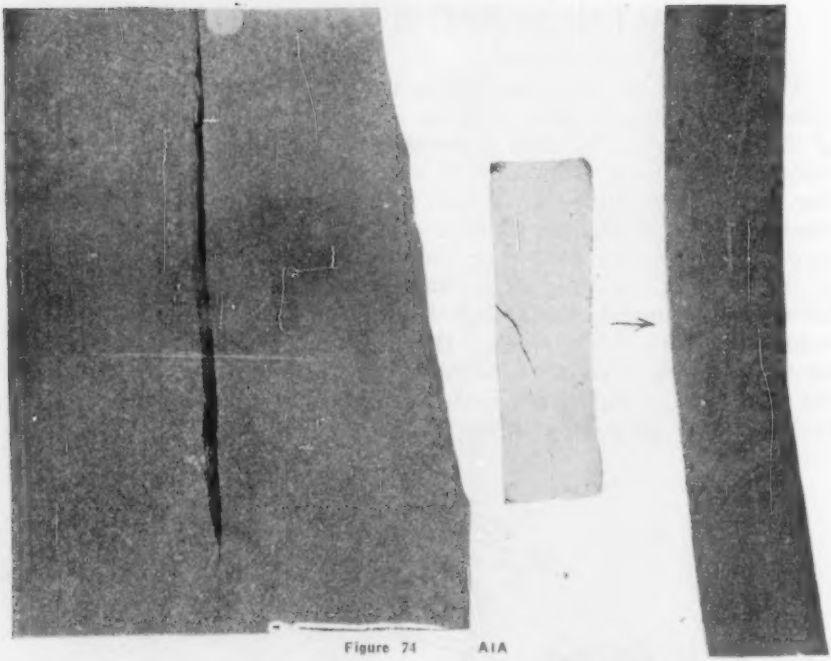


Figure 74 A1A

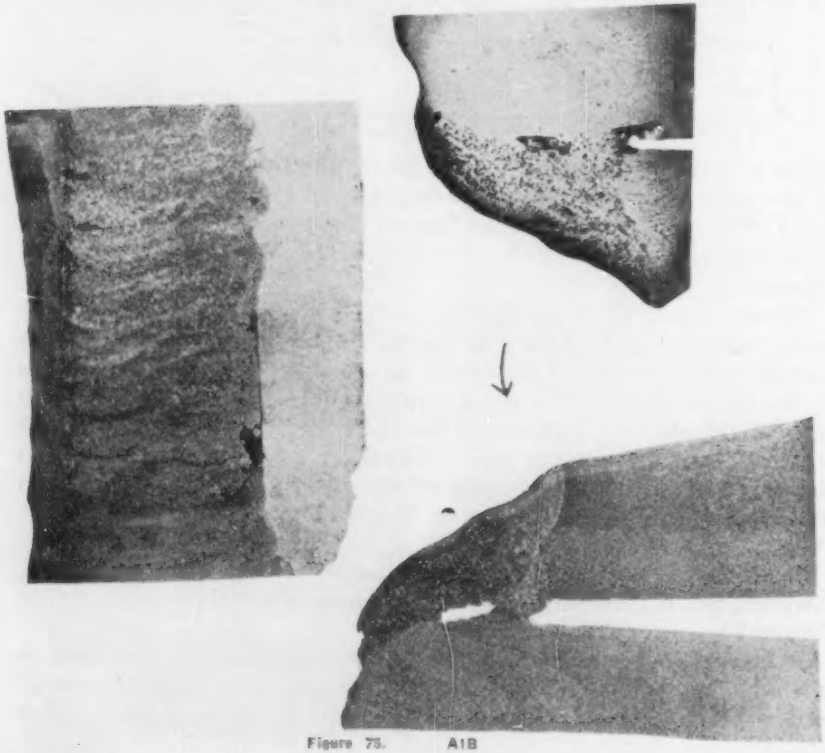


Figure 75. A1B

etching, the fused-in metal may ordinarily be distinguished from the metal of the plate by the darker color in the single or double Vee in the cross sections, and in the longitudinal sections by the darker color or by the crystalline appearance, and by the characteristic layers of the fused-in metal. The sections of the welds at the heads of the tank can be recognized by their shape. The longitudinal and transverse sections can be easily distinguished. A few of the sections represent the plates in the unwelded portions, in those tanks in which failure first appeared in the plate at some dis-

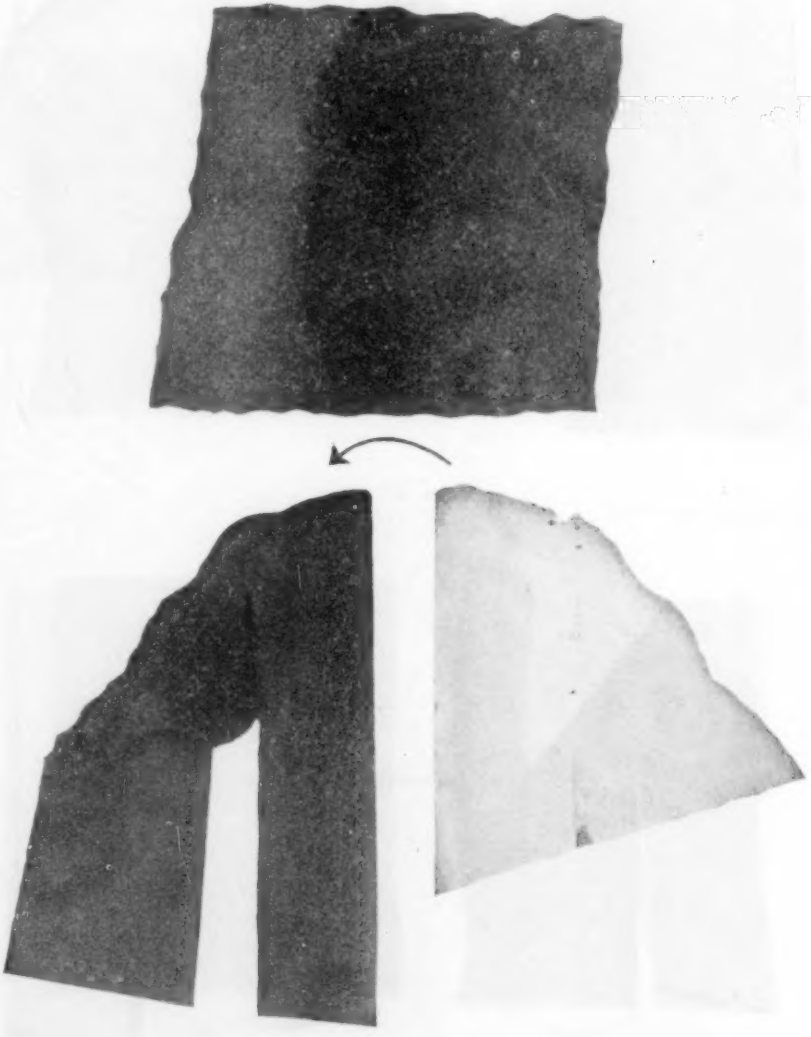


Figure 26. A2A

tance from the weld. The grain structure in the weld and in the plate, as well as any streakiness can be seen in the etched sections; in the polished, but unetched, sections the relative cleanness and soundness of the metal is more readily revealed than after etching. The polished sections, in the assembled photographs, are connected by arrows to the corresponding etched sections. A line drawn

Figure 77 A3

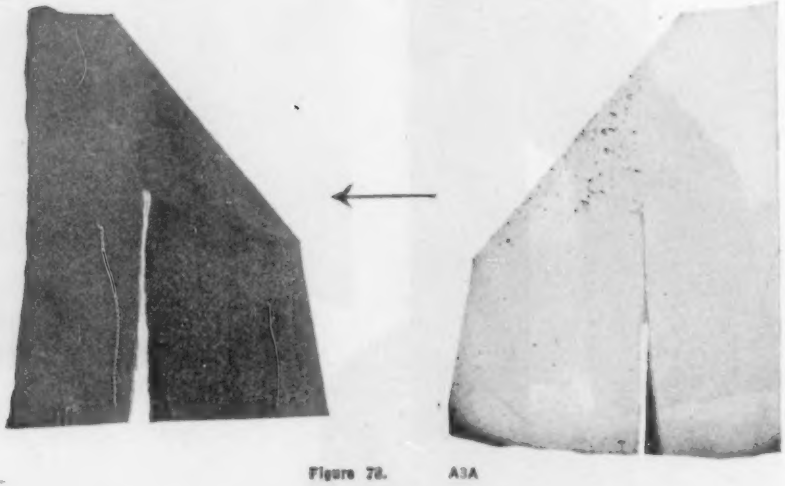


Figure 78. A3A

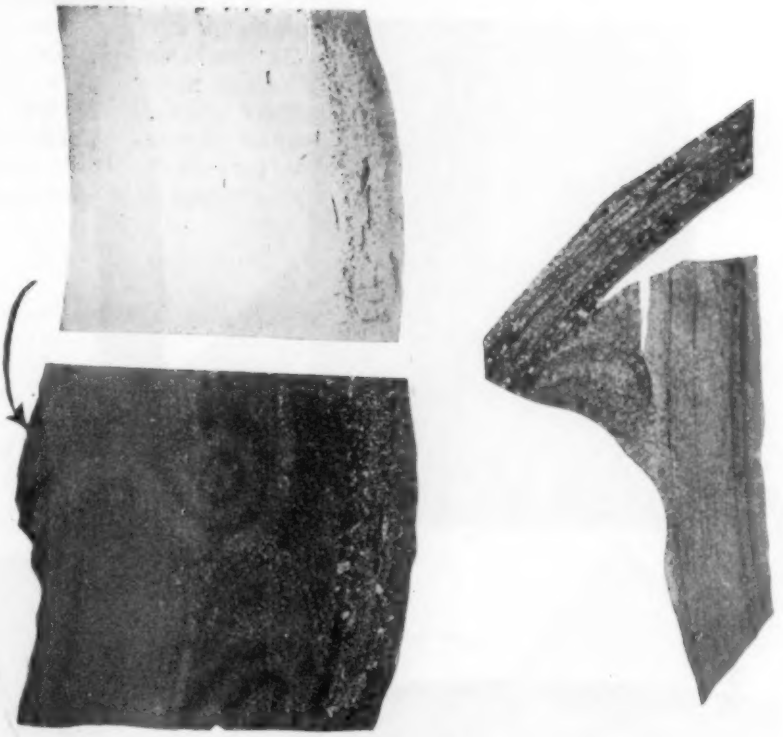


Figure 79. B1A

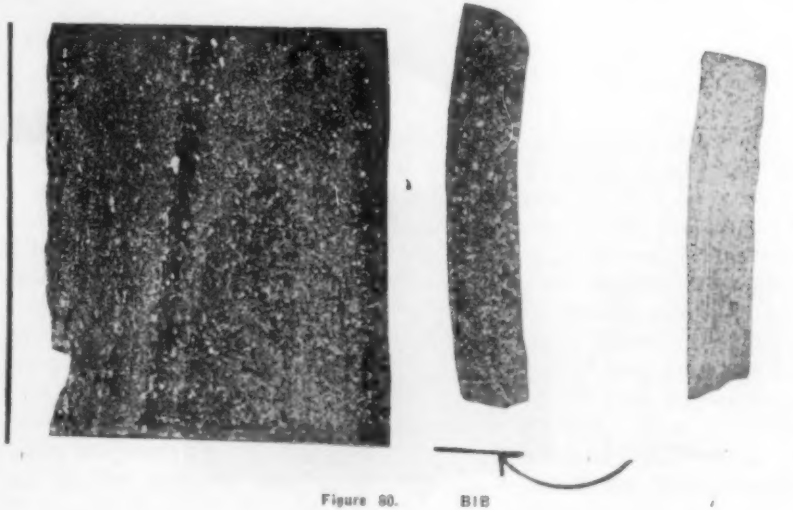


Figure 80. B1B

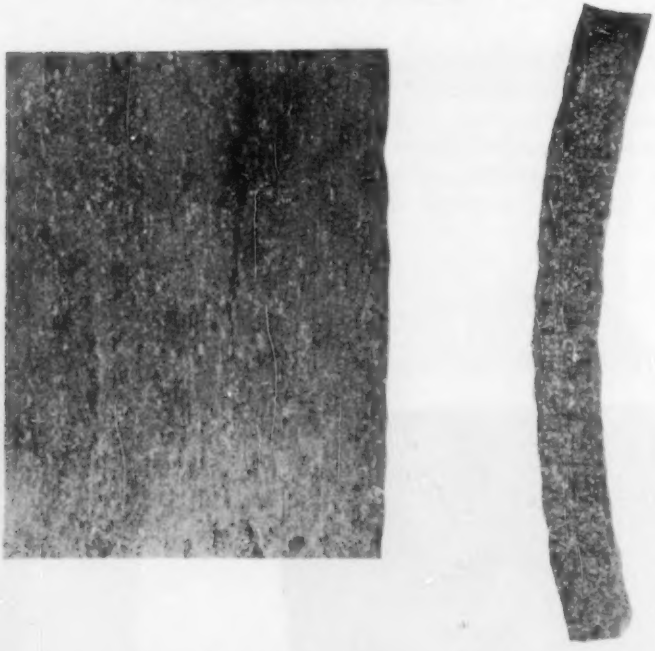


Figure 81. B2A

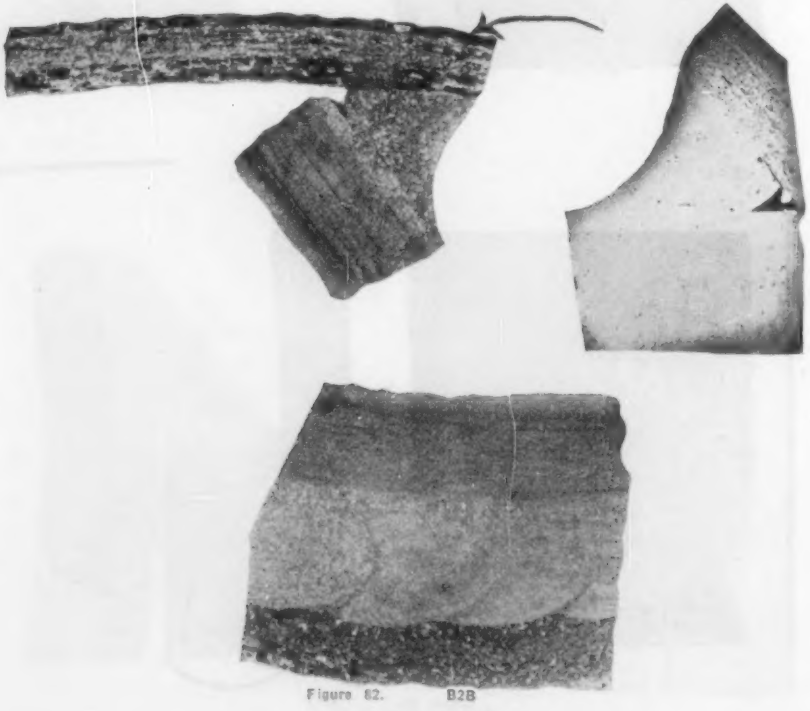


Figure 82. B2B

parallel to the side of a section indicates the face on which fracture occurred. From the photographs, any exceptionally clean metal in the fused-in metal and at the boundaries can be easily recognized. The relative grain size of the plates at the welds can also be seen.

The characteristic features of the different welds are so varied and often appear to be peculiar to the particular specimen under examination, so that no generalizations have been attempted. Reference must be made to the photographs themselves, and compari-

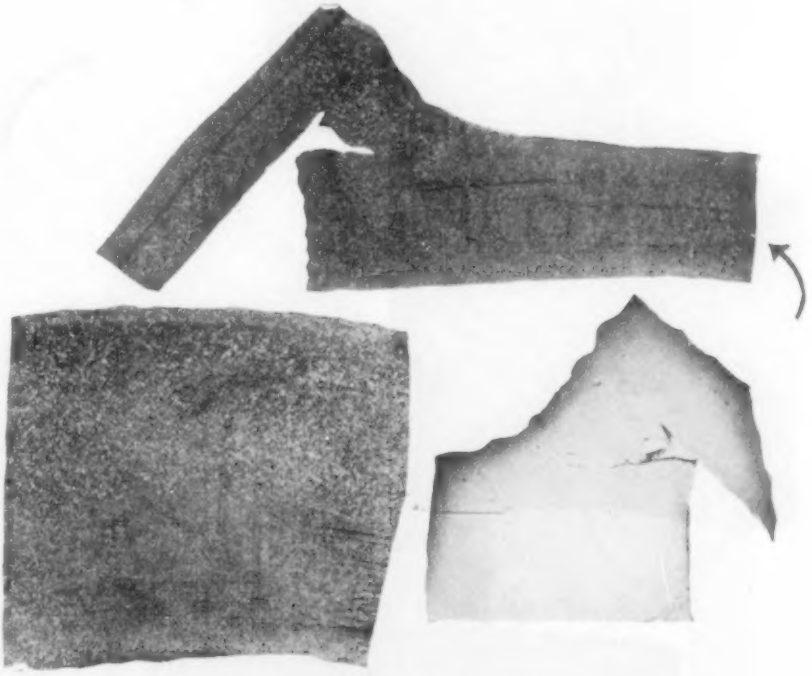


Figure 83. B3A

sons made with the results presented in the previous report.

The following example is cited to illustrate the fact that the structural character of the weld metal cannot be used as a single criterion in judging betwen welds, particularly if the welds are of different design. Welded tank G3 failed at a stress of approximately 44500 lb./in^2, one of the lowest of the double-Vee welded tanks. The metal of one of the Vees was very porous and unsound. The weld of specimen X—15, a tank of a special type in which the single Vee extended approximately only one half way through the plate thickness, was almost perfect in its structural appearance, both macro—and microscopic. It failed however, at a *very* low stress, less than 10,000 lbs./in.^{2}. The coarsening of the grain structure by the welding heat is evident in most of the photographs.

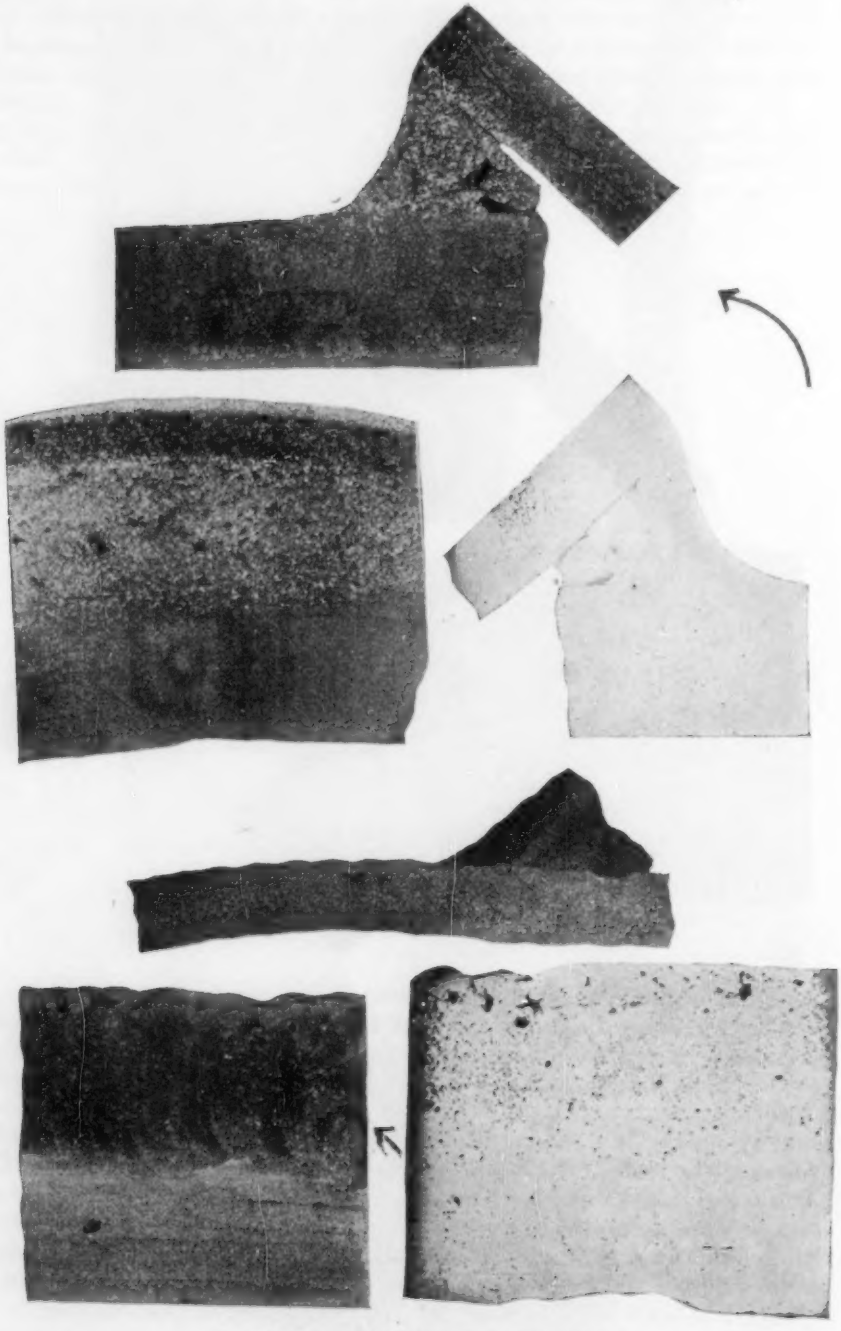


Figure 84. B3B (upper three photographs)
Figure 85. C2A (lower three photographs)

This condition could be remedied somewhat by a simple localized annealing treatment of the welded portion. It should be borne in mind, however, that some differences in structure will always remain after any local heat-treatment on account of the temperature gradient between the cold and the heated portions.

Figure 86. C2B

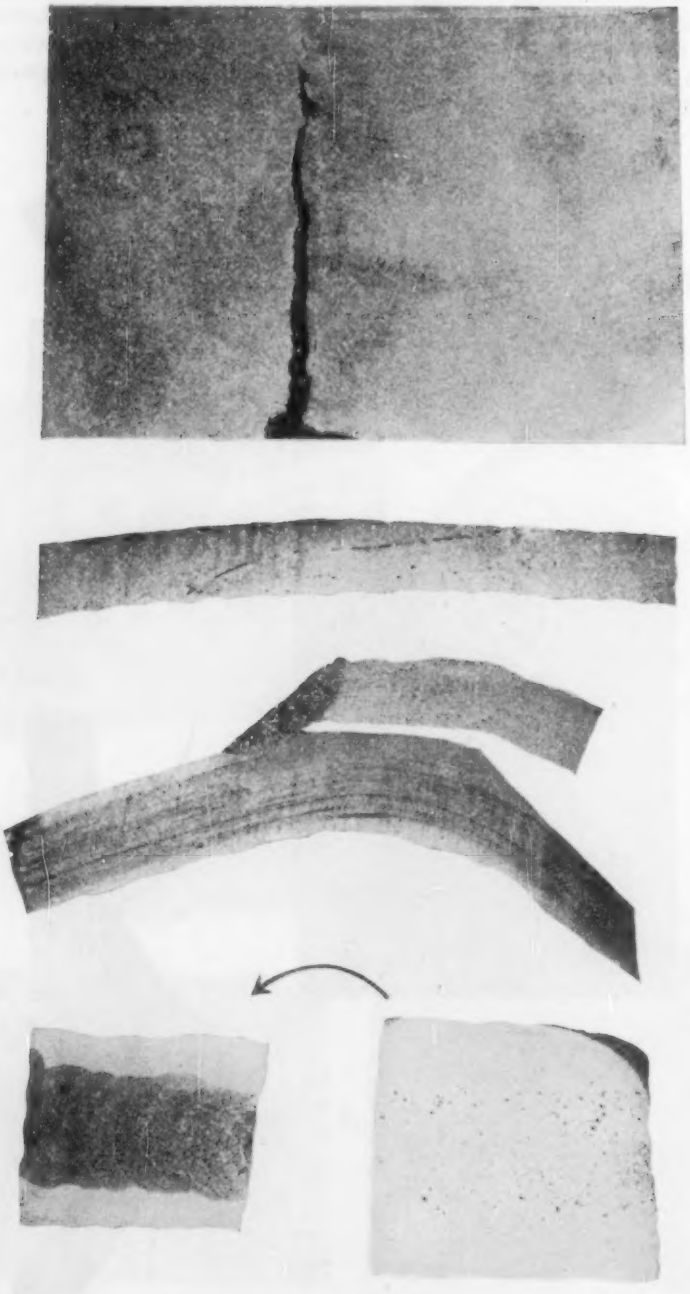


Figure 87. DIA

Microstructure.

A systematic study of the miscrostructure of the welds such as is described in Bureau of Standards Technologic Paper 170, on the Electric Arc Welding of Steel was not undertaken. It is generally believed that the miscrostructural features of fusion welds have a negligible influence on the properties of the weld, as compared with the grosser imperfections such as may be observed with the unaided

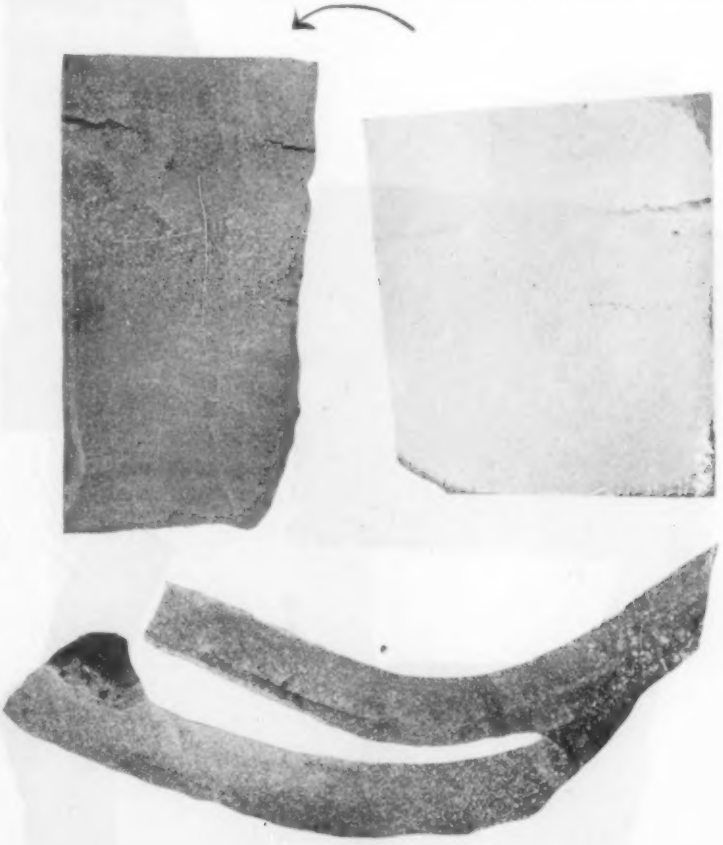


Figure 88. D2B

eye and which are shown in the natural-size photographs. Some typical micrographs were taken however, for purposes of illustration to show what may be expected in welds of widely differing quality. These are shown in the following micrographs.

In sample G3H, one of the Vees of the double-Vee was clean, the other not. Figure 110 shows the difference in the microstructure between these two portions and may be taken as representative in general, of the microstructure of clean and unclean welds and

parts of welds, as shown in the photographs of the polished sections. Figure 111 shows the appearance of the plate of H3B, which contained an excessive number of blow-holes and inclusions (oxide?). Figure 112-a shows a part of the boundary between the fused-in metal and the plate in G3H, which contained a number

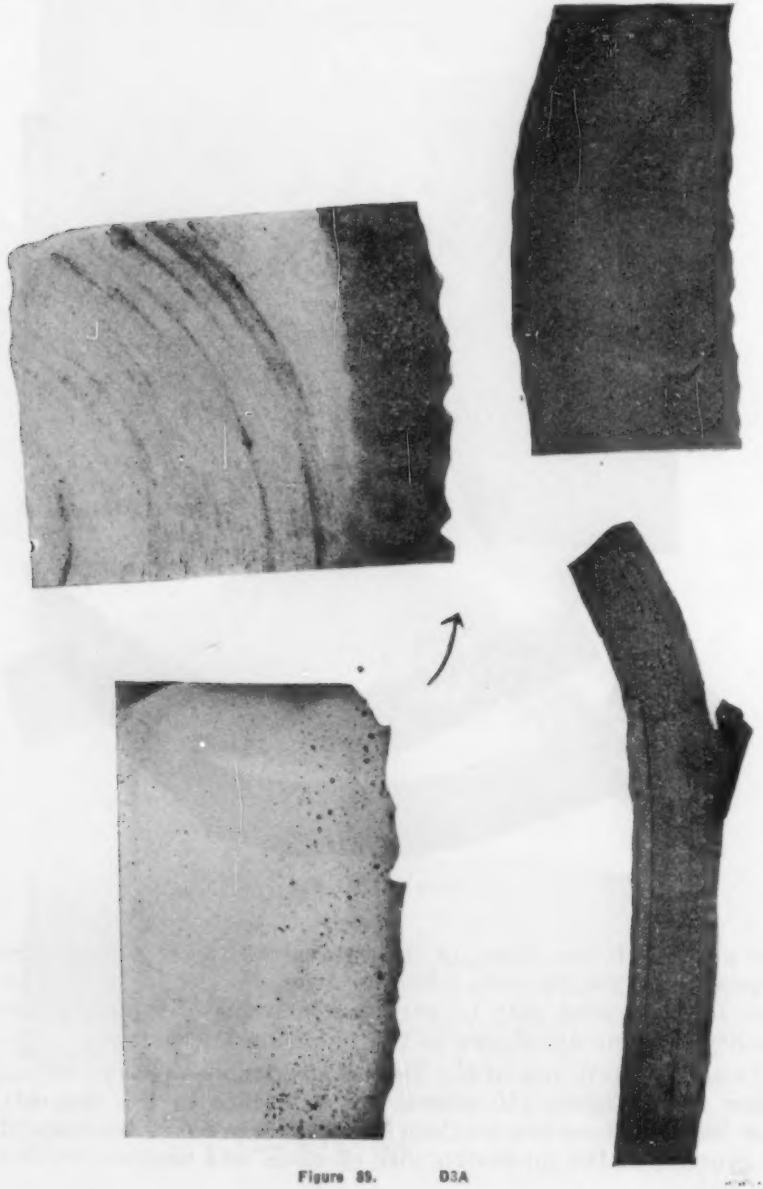


Figure 89. D3A

of cavities and inclusions; Figure 112-b, the same sample in another part where the boundary line could not be distinguished in the polished section. After etching with 5% Alcoholic Picric Acid, the boundary line is made perceptible by the difference in structure between the fused-in metal and the plate, but there are no inclusions or cavities to mark the course of the boundary. In the photographs of the polished sections such clean boundaries cannot be

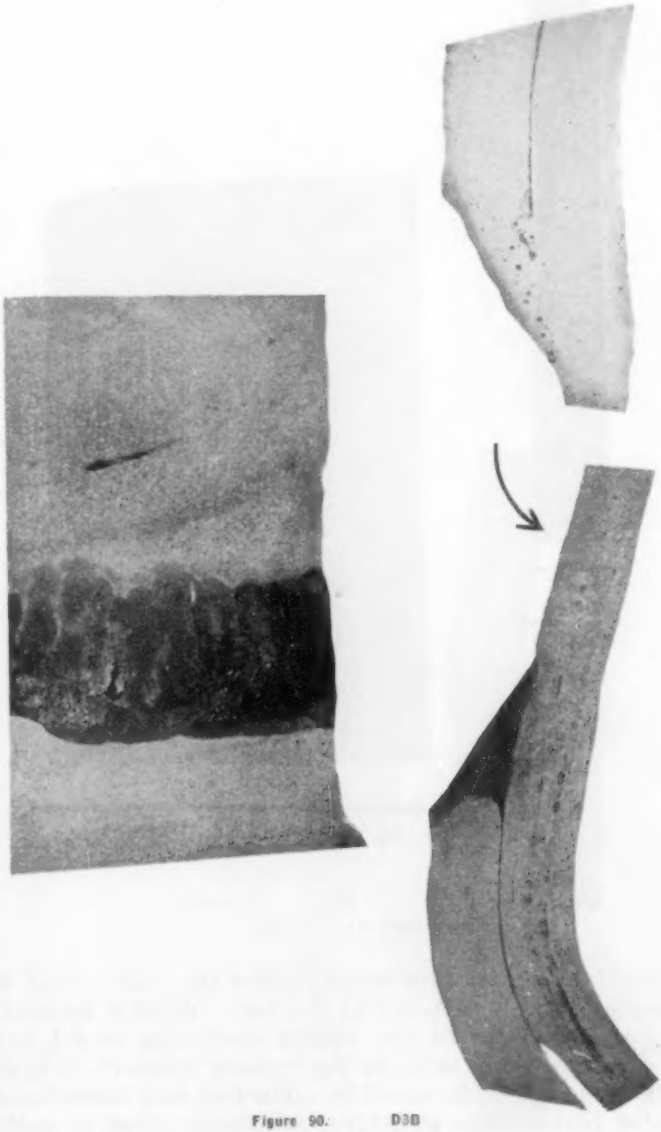


Figure 90. D3B

detected. Micrograph (Fig. 113) of B2B shows the general structure of the fused-metal in a clean spot; while micrograph (Fig. 114) of B2B shows the structure of the wrought iron which composed one of the plates,. The wrought iron plates can be recognized in the etched sections by the coarse crystalline appearance and streakiness, and in the polished sections by the streakiness. Figure

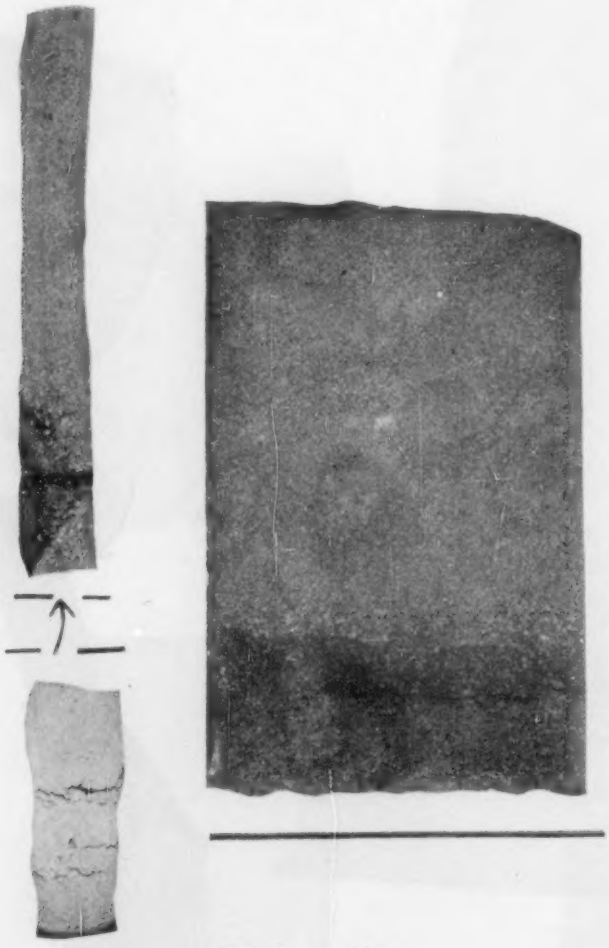


Figure 91. F2A

115 shows the slag and dirt which located the crack which formed in the plate of Tank A1A during the test. While a detailed study of the microstructure of the welded specimens would undoubtedly be of interest and value to the welding industry, it is difficult to see how much results could be embodied into acceptance tests for welded tanks. The structural difference noted in such spec-

imens are often peculiar to the particular specimen under observation so that generalizations relating to the series as a whole are practically impossible.

Summary.

1. The photographs given of the different welds illustrate the

Figure 92. F2B

types of structural variations which may exist in the welded tanks, all of which passed the "acceptance pressure" test of 1½ times the working pressure. The results of such examinations, however, do not lend themselves readily to generalization and no conclusion of *general* application to the whole series can be drawn.

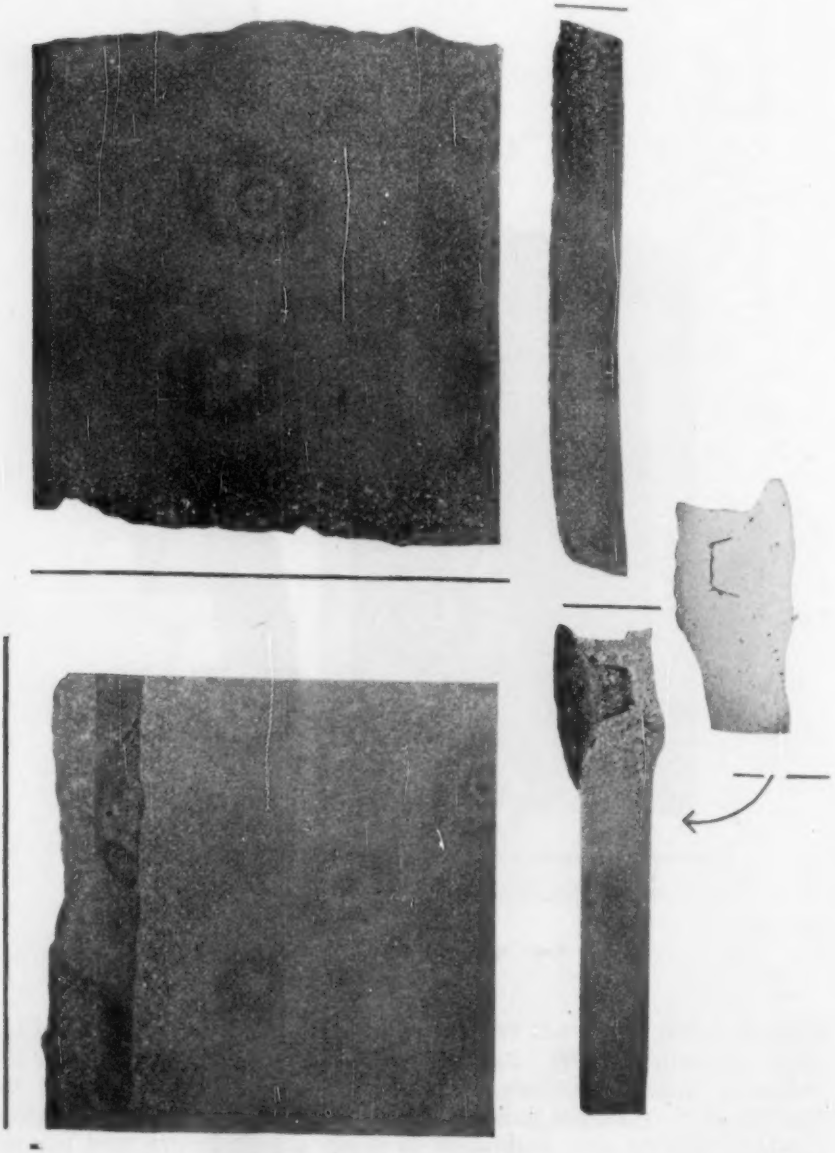


Figure 93. GIA

2. For inspection of the character of any particular weld, the macroscopic (low-magnification) examination will be found useful. The principal macroscopic structural features which determine the properties of the weld are 1, the physical soundness of the fused-in metal—porosity, "blow-holes" etc.) ; 2, the character of the

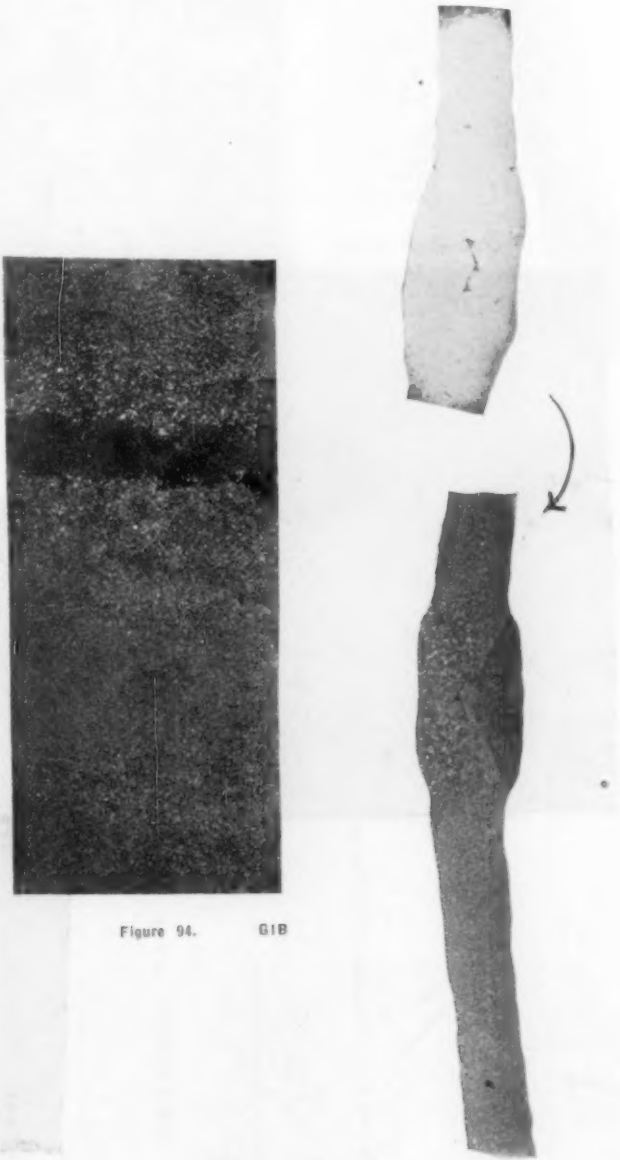


Figure 94. GIB

union between the welded plate and the fused-in metal; and 3, the amount and extent of the overheating of the metal in the neighborhood of the weld as revealed by the coarsening of the grain.

3. The microscopic examination is more suited for investigative purposes than for a routine examination and the results of the examination of these specimens do not suggest the desirability of including such an examination into any acceptance test.

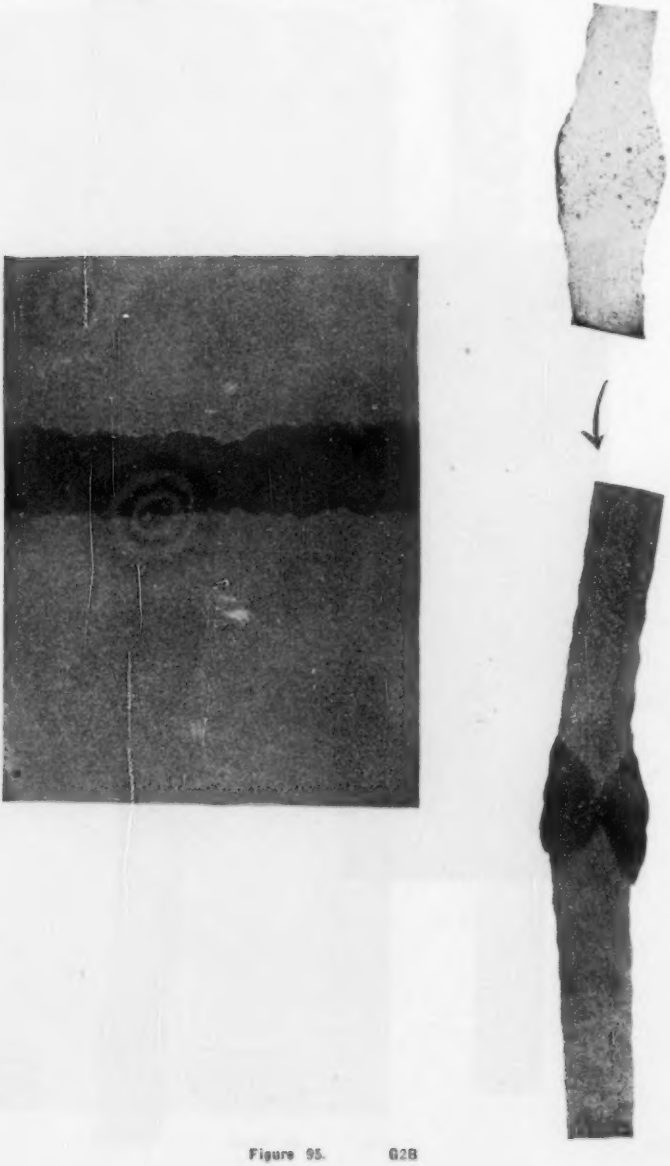


Figure 95. G2B

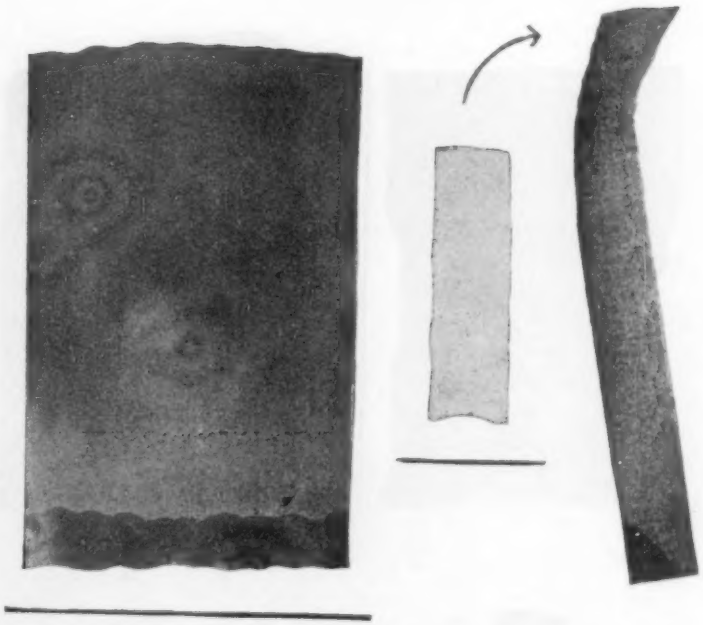


Figure 96. G2H

SUMMARY OF METALLOGRAPHIC EXAMINATION

Tank	Specimen	No. Macrographs	No. Micrographs
A 1	A	3	1
A 1	B	3	
A 2	A	3	
A 3		3	
A 3	A	2	
B 1	A	3	
B 1	B	3	
B 2	A	2	
B 2	B	3	2
B 3	A	3	
B 3	B	3	
C 2	A	3	
C 2	B	3	
D 1		5	
D 2	B	3	
D 3	A	4	
D 3	B	3	
F 2	A	3	
F 2	B	3	
G 1	A	5	
G 1	B	3	
G 2	B	3	
G 2	H	6	4
G 3	B	3	
G 3	H	3	
H 2		3	

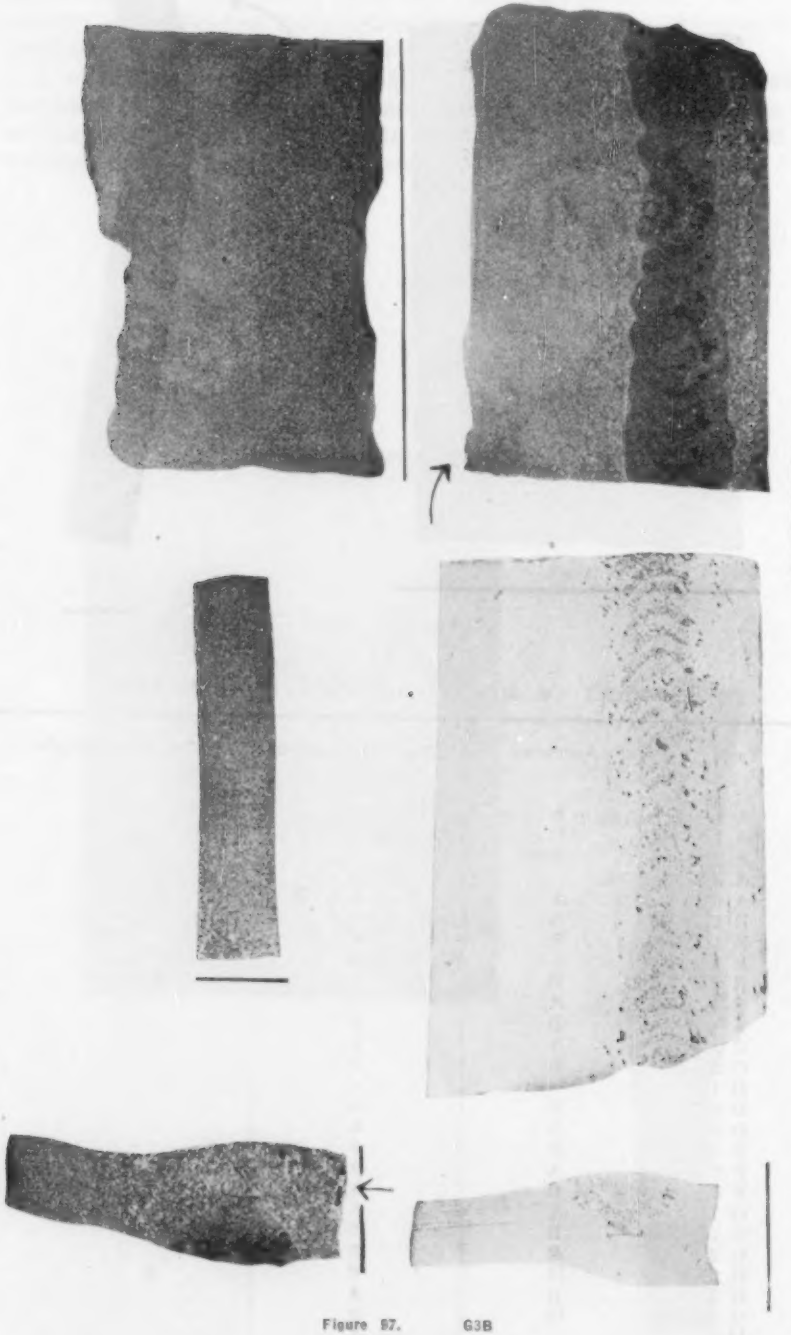


Figure 97. G3B

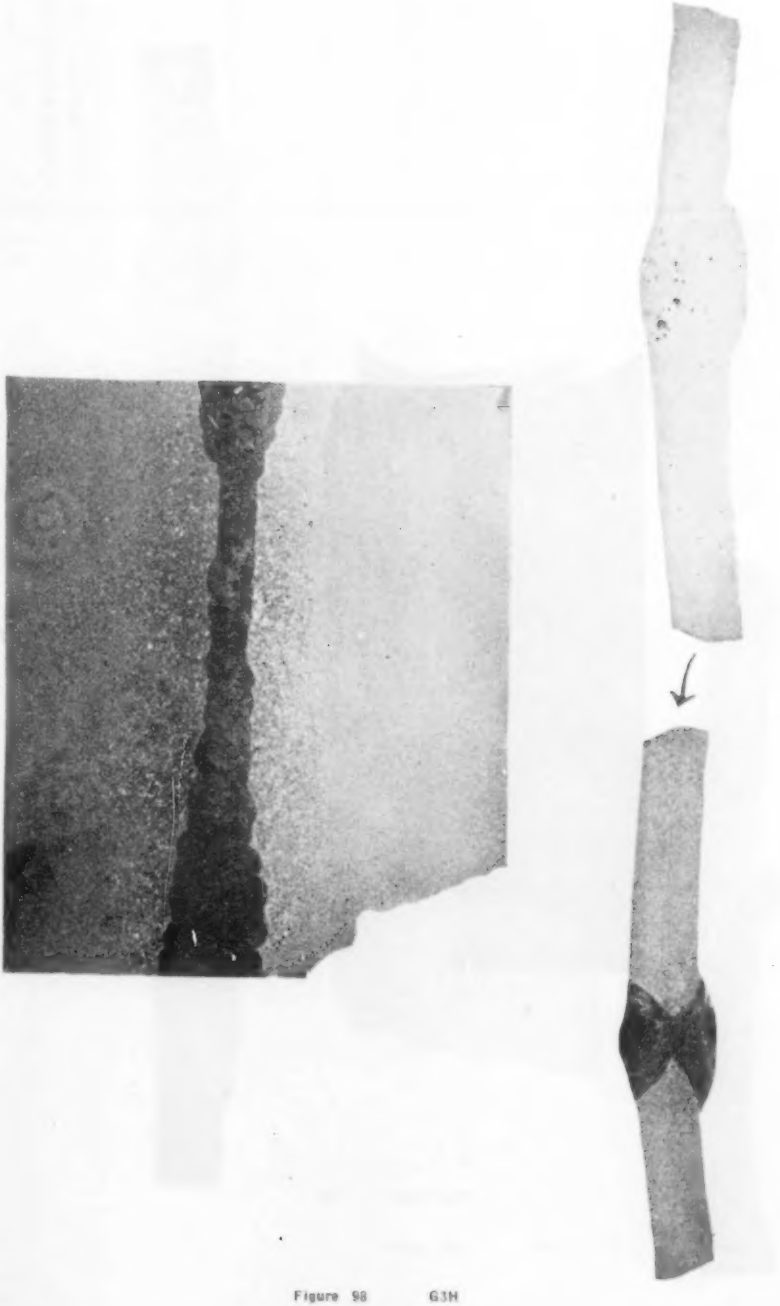


Figure 98 G3H

Figure 99. H2

SUMMARY OF METALLOGRAPHIC EXAMINATION (Continued)

Tank	Specimen	No Macrographs	No. Micrographs
H 3	A	3	1
H 3	B	3	
K 1	A	3	
K 1	B	3	
K 2	A	3	
K 2	B	3	
R K	4	5	
X 14		3	
X 15	B	3	
X 15	P	5	

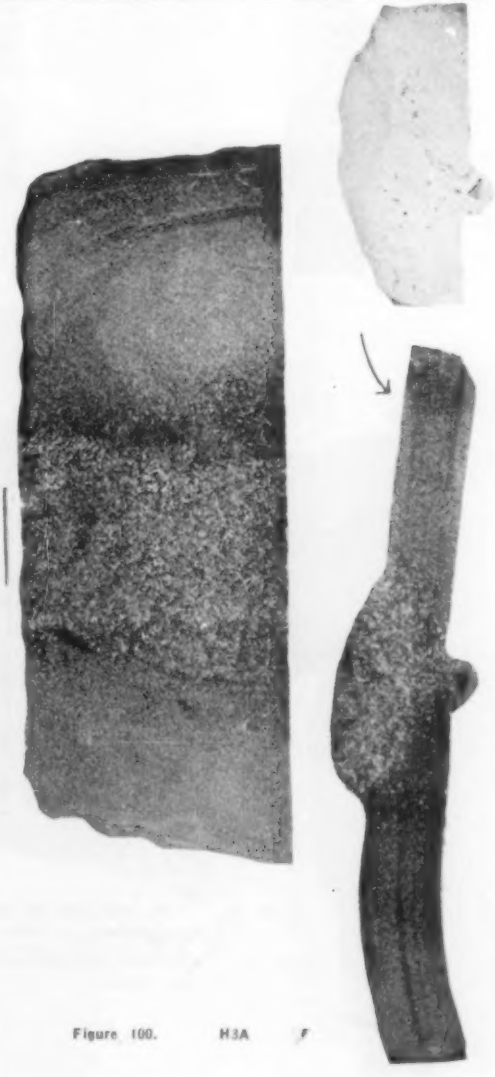


Figure 100. H3A F

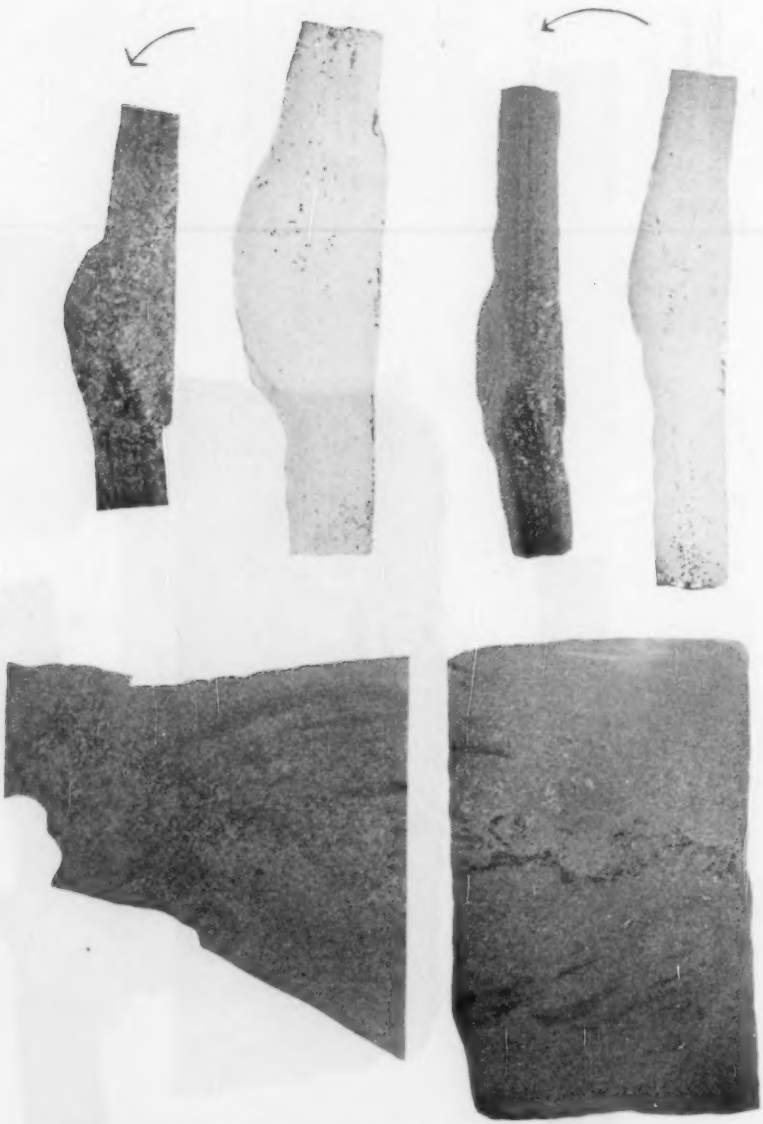


Figure 101. H-3B (upper two left hand and lower left hand figures).

Figure 102. K1A (upper two right hand and lower right hand figures).

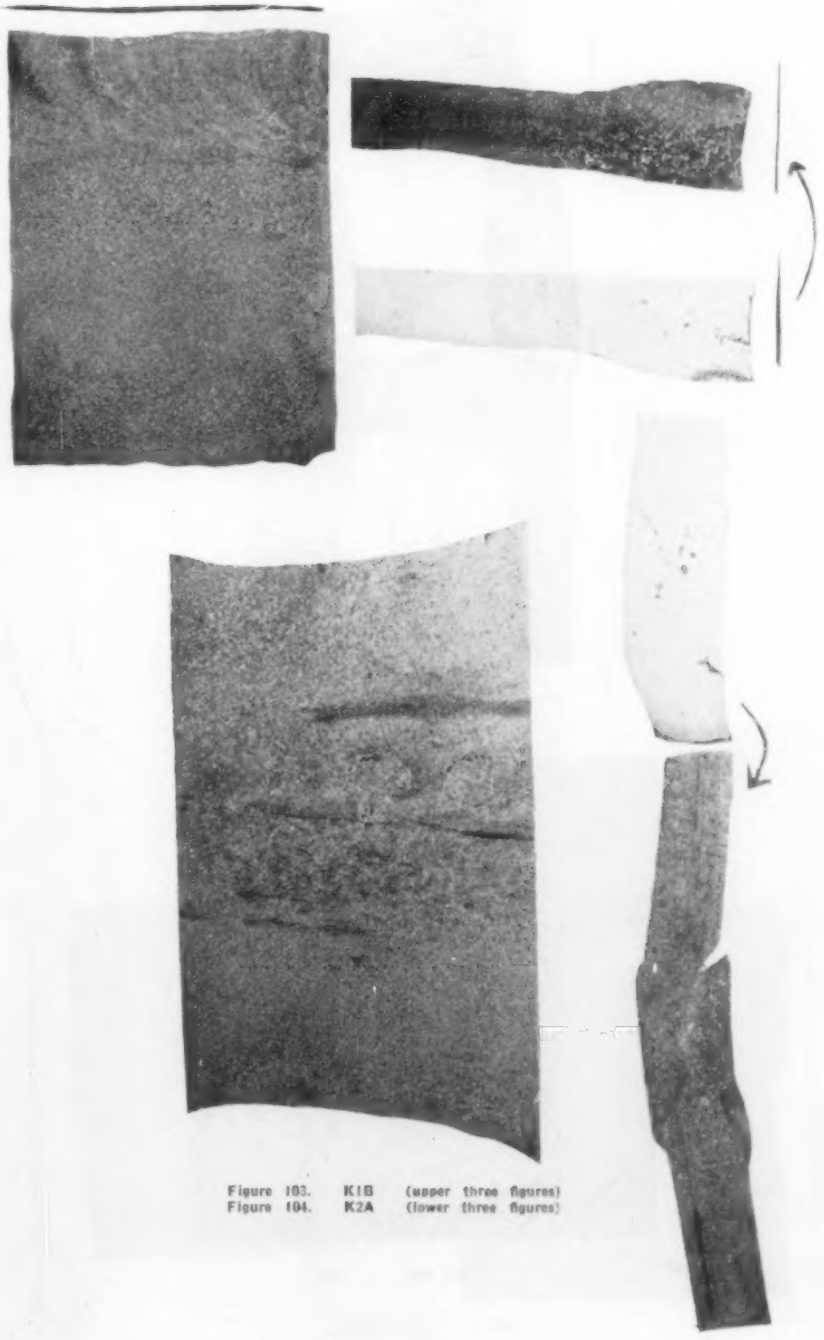


Figure 103. K1B (upper three figures)
Figure 104. K2A (lower three figures)

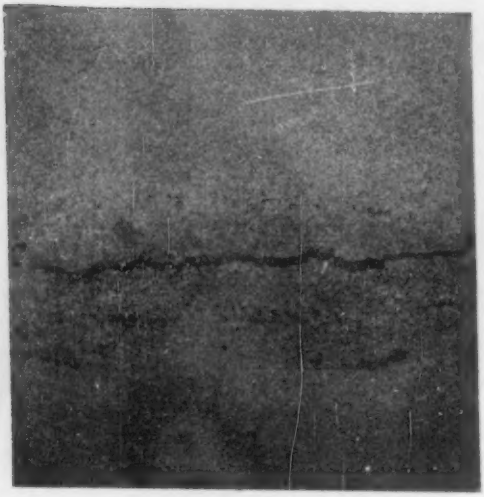


Figure 105. K2B

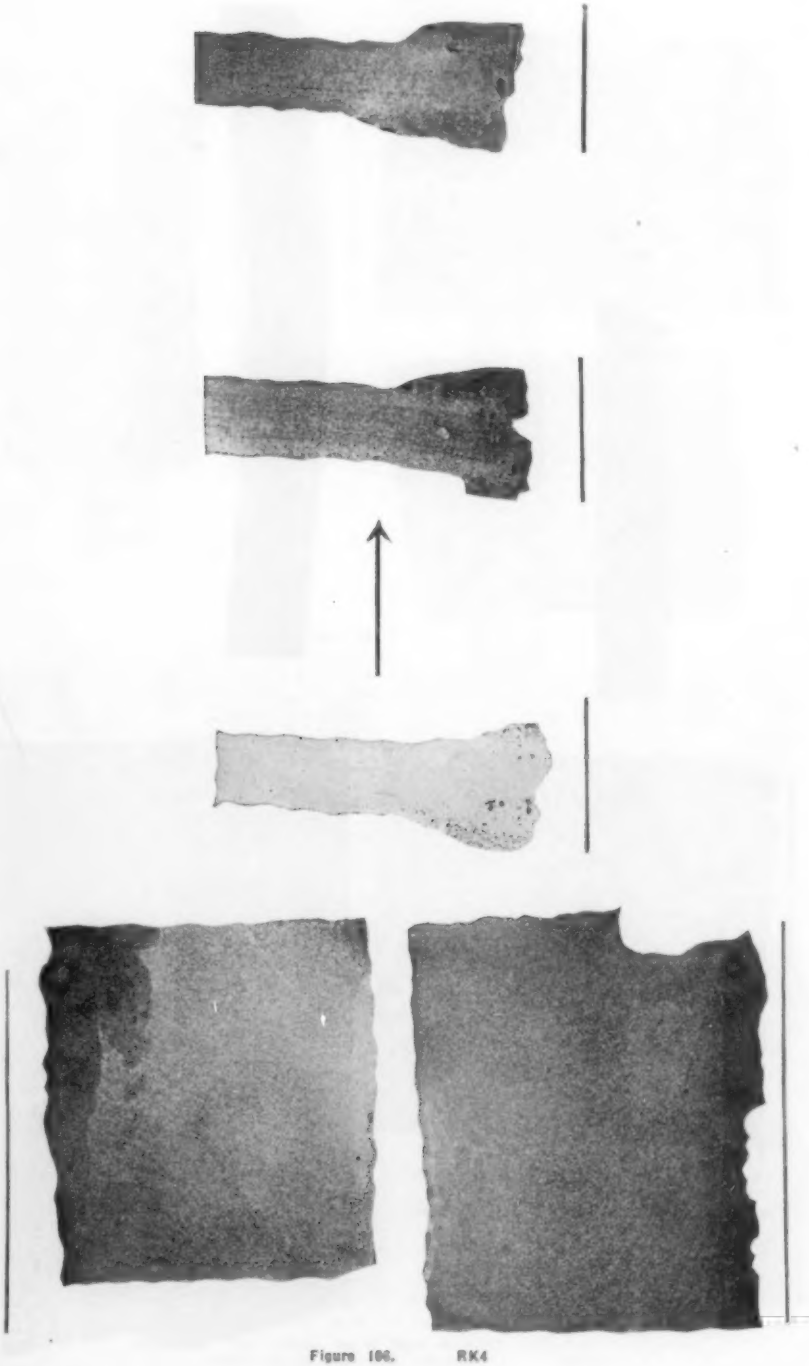
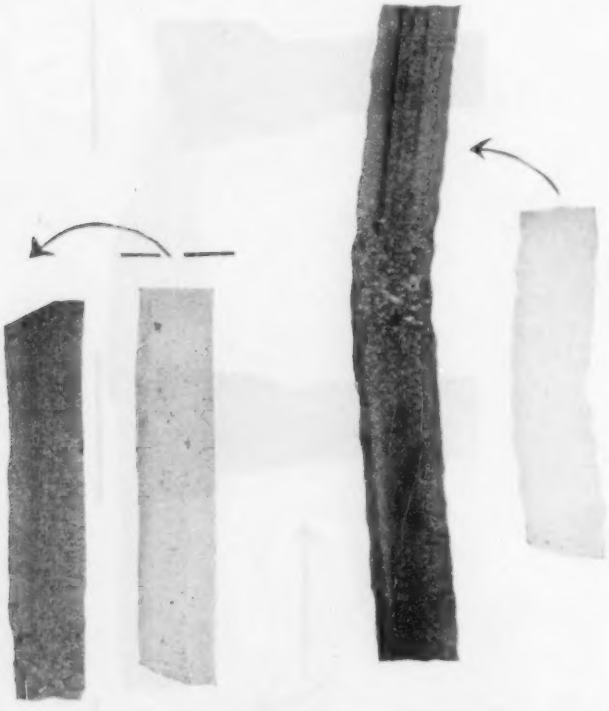


Figure 106. RK4



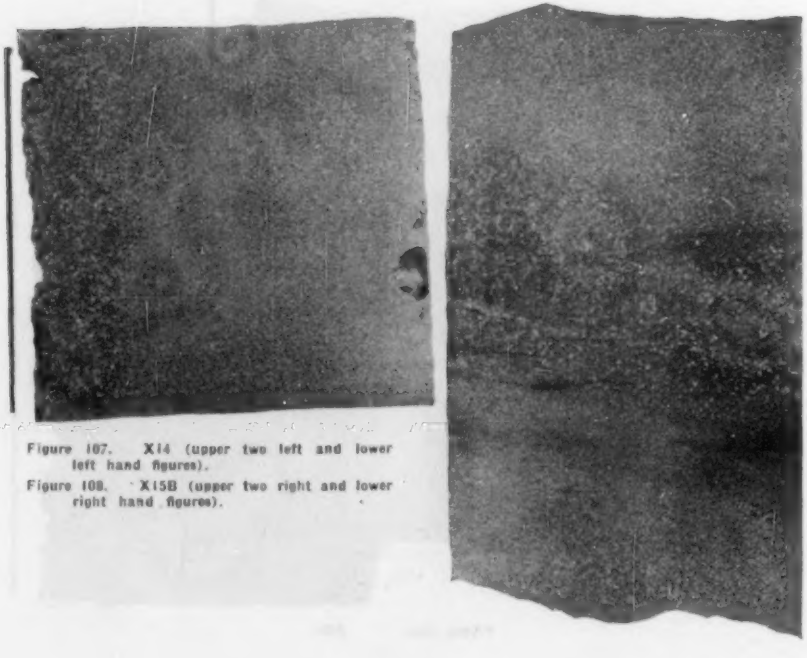


Figure 107. X14 (upper two left and lower left hand figures).

Figure 108. X15B (upper two right and lower right hand figures).

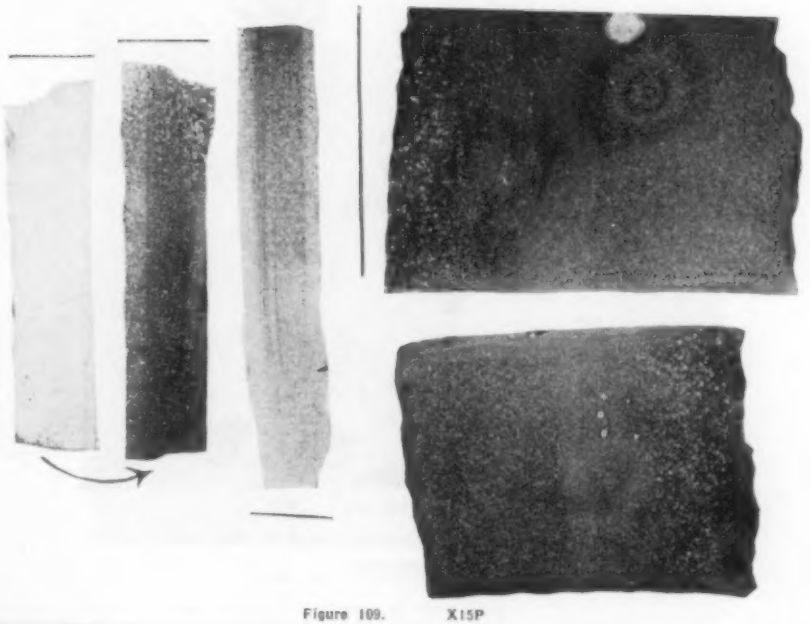
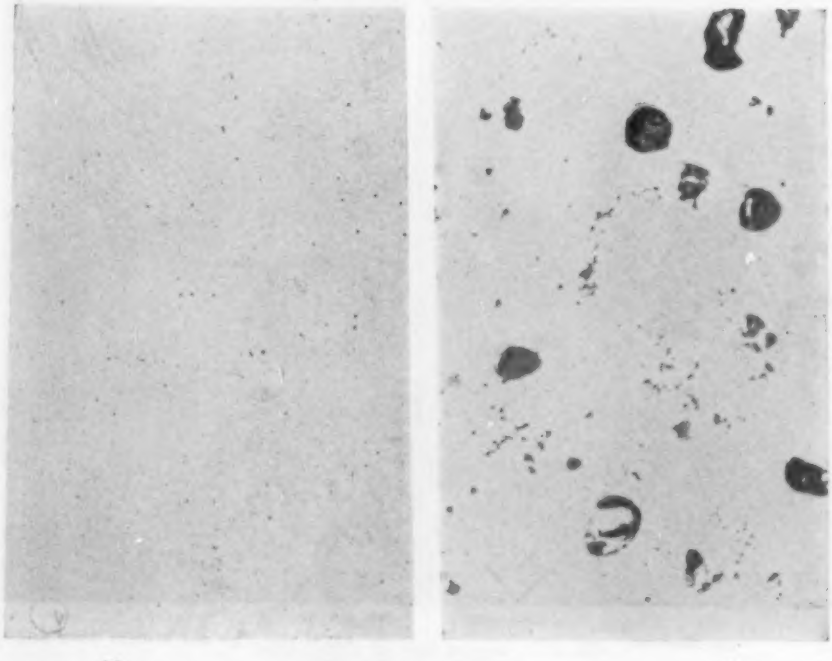


Figure 109. X15P



(a) (b)

Figure 110. (a) Clean Vee of Weld of G-311. (d) Unclean Vee of weld G3H. Unetched. 100-X

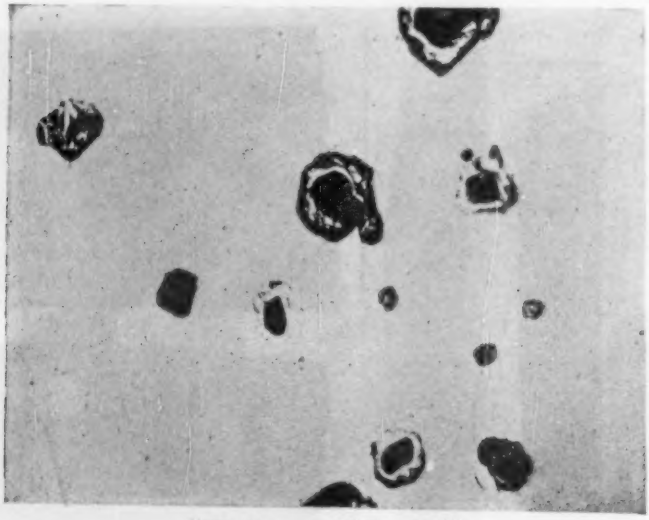
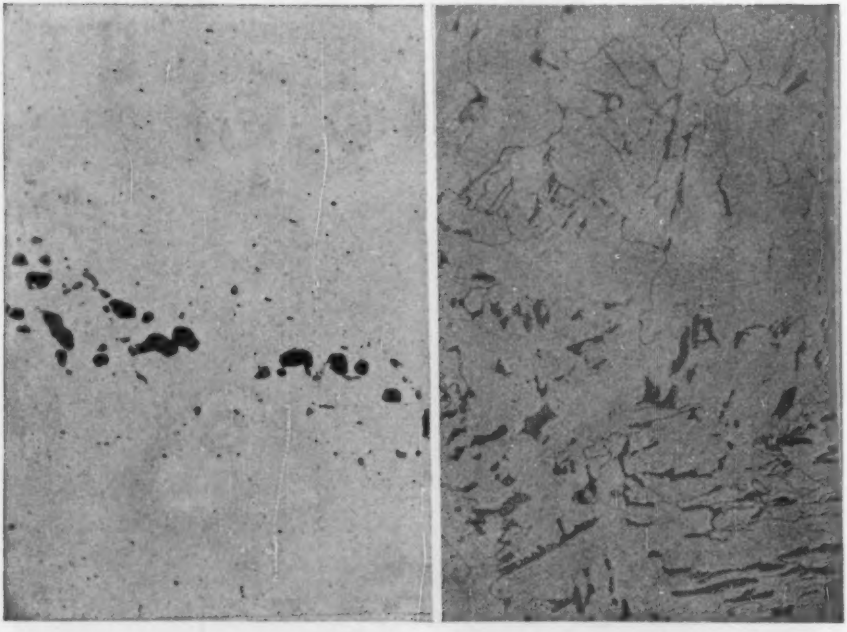


Figure 111. Unetched. 100X

Plate of H3B containing excessive number of blow-holes and inclusions.



(a) Unetched (b) Etched with 5 per cent Alcoholic Picric Acid.

Figure 112 Mag. 100X

(a) Dirt and cavities in boundry of G3H

(b) Clean boundry of G3H

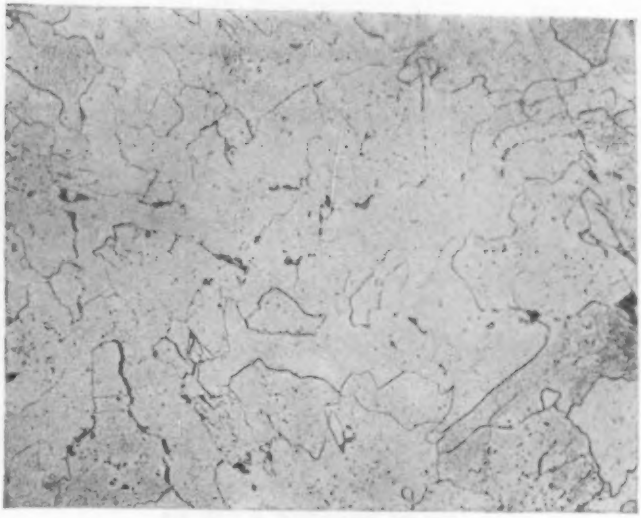


Figure 113. Specimen B3B Mag. 100X
Structure of Fused Metal
Etched with 5 per cent Alcoholic Picric Acid

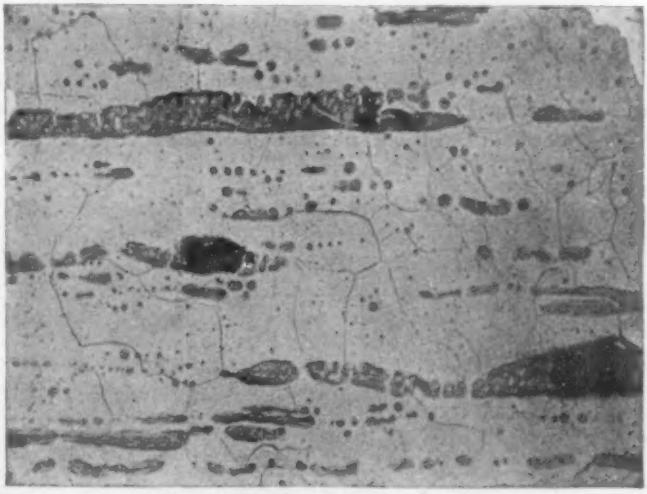


Figure 114. Mag. 100X
Etched with 5 per cent Alcoholic Picric Acid.
Structure of Wrought Iron of the Plate B2B

Figure 115. Unetched. Mag. 100X
Slag and Dirt in Crack in Plate A1A

METALLOGRAPHIC EXAMINATION OF WELD IN ELECTRIC-ARC-WELDED TANK, NO K-4

The tank failed under the hammer with a hydraulic pressure of 300 pounds per square inch. A crack, approximately 5 inches in length, opened in the circumferential weld at one end and allowed the water to escape. This portion of the weld was removed by drilling and constituted the specimen used for examination. *Figure 116, natural size shows the crack in the weld as it appeared on the outer surface of the specimen; the inner side is shown in Figure 117.

Figure 116 (outer side)

The crack, although it could be seen in places that it extended completely through, did not show up as prominently on the inner as on the outer. The location of the crack on the inner side is indicated by the arrow. The crack is barely visible.

Figure 117. (Inner side).

Figure 118. (Ends of Specimen, Natural Size).

Upon grinding down the surface of the weld the crack was seen to be much longer than it appeared before. Figure 118 shows the ends of the specimen. The crack extended almost completely to the ends and not only through the center as shown in Figure 116.

Figure 119 (x 2½) shows a cross section of the specimen polished and etched with ammonium persulphate. In the photograph there can be distinguished the fused metal, the refined zone, and the unchanged steel plate. The crack starts at the juncture between the fused metal and the steel and goes through the fused metal. The juncture between the fused metal and the steel of the plate appears sound and so proved to be upon microscopic examination.

*Tank K-4 was rewelded after removal of this specimen and tested again.

Micrograph (Fig. 120) (X-100, etching 5% picric acid in alcohol) shows the crack. It can be seen that the crack consisted of a network of smaller cracks. This indicates that the cracking oc-

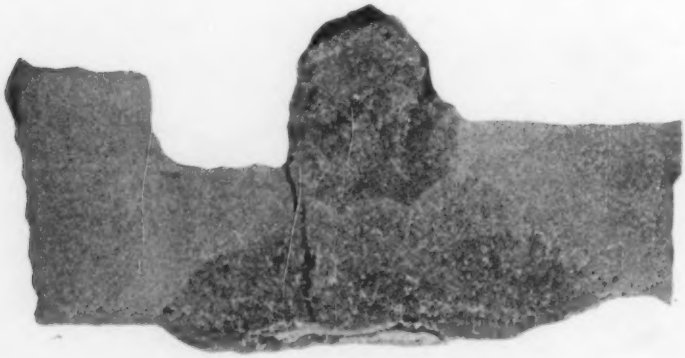


Figure 119. (cross-section etched and enlarged 2½ times).

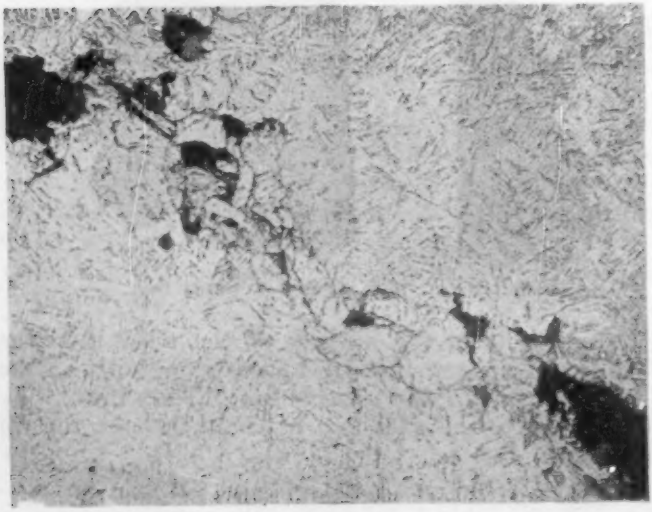


Figure 120. (X100)

curred at a high temperature when the fused metal was red-short and under the action of contraction stresses. Single impact stresses, such as hammer blow, would not produce a network of cracks of the kind shown. The general course of the crack was determined by the 'pores' and 'blow-holes' in the weld metal.

CURRENT WELDING LITERATURE

Arc Welding, Electric-Arc Welding Machine, J. W. Fay, U. S. Pat. 1446170 Off. Gaz. (Feb. 20, 1923), Vol. 307, p. 677.

Arc Welding, Electric, J. Caldwell, Metal Ind. London (Feb. 2, 1923), Vol. 22, pp. 101-3. Iron Arc Characteristics, Direct-Current Versus Alternating Current Welding.

Autogeneous Welding, Acetylene Generating Apparatus for Appareils Producteurs d'acetylene pour la soudur autogene. A Delamarre Outillage (Jan. 27, 1923), Vol. 296, pp. 91-4.

Arc Welding For Studs. The Handstock, Limited, Canadian Pat. 227825, Official Rec. (Jan. 9, 1923), Vol. 51, p. 89.

Autogeneous Welding Overheating Iron During. Uberhitzung des Eisens bei der Autogene Schweissung. T. Kautny. Acetylen (Dec. 1922), Vol 25 (Autogene Metallbearb). p. 69-72.

Brazing Locomotive Cylinders, A. L. Carnahan, Welding Engineer, Vol 8, (April 1923), pp. 28-9.

Cutting, Economy of Cutting Metals With the Electric Arc. A. M. Candy, Ry. Electrical Engineer, (Feb. 1923), Vol. 14, pp. 51-2.

Electric Arc Cutting. A. M. Candy, Welding Engineer, Vol. 8, (April 1923), pp. 36-8.

Electrode for Arc Welding. W. H. Boone, Canad. Pat. 228474. Off. Rec. (Feb. 6, 1923), Vol. 51, p. 289. Metallic core wound with carbonaceous fibre.

Extension of Oxy-Acetylene Welding Problems in Oil and Gas Industries, Acetylene Journal, Vol. 24, (April 1923, p. 494.

How Welded Joints Solve Pipe Line Troubles. Pamphlet published by Oxweld Acetylene Company. Pamphlet contains article by N. E. Wagner, Supt. Prairie Pipe Line Comptny, E. E. Lundgren, Western United Gas and Electric Company, and G. O. Carter, Linde Air Products Company.

Metals and Their Qualities for Welding and Cutting. Die Metalle und ihre Eignung for den Schweiss und Schneidprozess, W. Ritter. Maschin. Konst. (Jan. 12, 1923), Vol 56, pp. 19-22.

The Oxy-Acetylene Process, E. H. Smith, Welding Engineer, Vol. 8, (April 1923), pp. 24-5.

Oxy-Acetylene Welding in Coal Yards and Mines, Acetylene Journal, Vol. 24, (April 1923), pp. 488 and 492.

Safety in Compression of Gasses, A. D. Risteen, Acetylene Journal, Vol. 24, (April 1923), pp. 484 to 487.

Training Welding Operators, Welding Engineer, Vol. 8, (April 1923), p. 140 and 46.

Trade Catalogs. A catalog has been published by P. F. McDonald Company, Boston, 27 Massachusetts, describing their products of "Macco" steel.

The American Welding Society

The American Welding Society is organized to provide united and co-operative action in extending the knowledge of the art of welding and its field of industrial application. The field for further application of welding is enormous, and progress in it is being delayed only by incomplete knowledge and by the confusing and opposing claims of competing interests.

The Society acts as a clearing house for information. Through papers and monthly meetings of local sections of the Society an opportunity is created for the individual manufacturer, engineer, plant superintendent, foreman, operator, etc., to contribute his own knowledge in welding and at the same time receive the benefit of the combined knowledge and experience of all other members of the Society. Special publications in addition to the regular monthly proceedings are issued from time to time giving results of researches, standardization work and other information of value to the members.

CLASSES OF MEMBERSHIP

Extracts From By-Laws

ARTICLE I

Section 1. Individuals having received the approval of a majority of the Membership Committee shall become members of this Society upon the payment of dues, except in the case of honorary members who shall be elected by unanimous vote of the full Board of Directors.

Section 2. Membership shall be divided into five classes:

Class A. Sustaining members, being individuals or individuals delegated by corporations, firms, partnerships, etc., interested in science and art of welding, with full rights of membership. Annual dues $100.00

Class B. Members, being individuals interested in the science and art of welding, with full rights of membership. Engineers or individuals competent by experience or training to plan or direct welding operations are eligible to this class. Annual dues $20.00

Class C. Associate members with right to vote but *not* to hold office, except in Sections as may be provided for by the By-Laws of the Sections. Supervising welders, inspectors and skilled operators, with three or more year's practical experience in welding are also to this class. Annual Dues $10.00

Class D. Operating members, who are welders or cutters by occupation, without the right to vote or hold office except in Sections as may be provided for by the By-Laws of the Sections. Annual dues $5.00

Write to the Secretary for a membership blank.

K-G Welding & Cutting Company, Inc.

556 WEST 34th STREET

New York City

MANUFACTURERS OF K-G-TORCHES

WELDED PRESSURE VESSELS

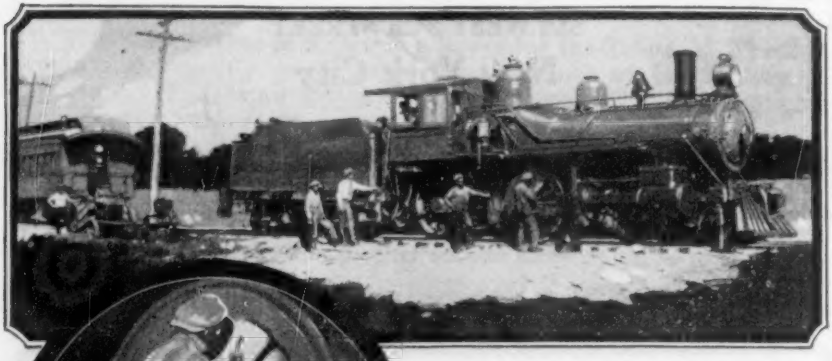
For several years efforts have been made to draw up a Code for the Welding of Unfired Pressure Vessels. Opinions of the best welding experts were not in agreement on many essential points. Fundamental scientific knowledge based on test data was not available. The American Bureau of Welding has completed a series of tests on some 47 tanks. The program involved an expenditure of over $15,000. The test data, analysis of same, conclusions and recommendations to the Boiler Code Committee of the A. S. M. E. have been compiled in a report, copies of which are available for distribution at $1.50 to members and $5.00 to non-members.

AMERICAN WELDING SOCIETY

33 West 39th Street

New York, N. Y.

They've Been Welding on the Railroad



This is a drawing from an actual photograph showing the broken frame of a locomotive that is being repaired with a Westinghouse arc-welding outfit—not in the shops but on the right-of-way

Electric Welding

Saves Time—Money—Material

A broken frame stopped this locomotive and threatened a trip to the shops, a disorganized schedule, a long delay for passengers and express matter, and a cost that would have been very serious.

But a Westinghouse salesman happened along!

After that, it was only a matter of a few hours till the train was on its way again; the frame *permanently* and *properly* repaired by a portable welding set which had been operated by the same tractor that drew it out from a nearby town. Just think about that a minute!

What do they do in *your* business? Do they weld, or do they wait? Do you, and your plant people, know of the great advantages that electric welding would bring to you? Perhaps you have no idea of the value of the machines and parts that are scrapped or laid up every year just because arc-welding isn't known, or its practical uses understood.

Westinghouse makes arc-welding apparatus for every purpose including a one-man set that can be *taken to the work*. And every manufacturer ought to know of their possibilities for there are few plants in which they will not quickly pay for themselves. Our nearest office will gladly tell you the interesting facts about them.

WESTINGHOUSE
ELECTRIC & MANUFACTURING COMPANY
Offices in all Principal Cities · Representatives Everywhere

© 1923 W. E. & M. Co.

Westinghouse

1923 W. E. & M. Co.

Take the GUESS WORK Out of Welding

IN YOUR PLANT there is a man who needs timely and accurate information about welding. He should know what is being done in other plants to reduce costs and increase efficiency. No matter what your welding problem may be, The Welding Engineer is the best source of information, the best adviser you could have. Every phase of welding, both manufacturing and repair problems, is discussed fully in this valuable monthly publication. The best authorities in America on the subject of welding are regular contributors.

Every process of welding is discussed by The Welding Engineer. Arc Welding, Electric Butt, Spot and Seam Welding, Oxy-Acetylene and the Thermit System, in fact every known process of joining metals is discussed. Its Buyers' Index reflects the progressiveness of America's first manufacturers.

L. B. MACKENZIE, Editor H. S. CARD, Associate Editor

Price $3.00 In The United States And Canada, $4.00 Abroad.

Write for free sample copy for convincing proof that The Welding Engineer is indispensable in your business.

Member Audit Bureau of Circulations

The Welding Engineer

608 S. DEARBORN STREET, CHICAGO

Member Associated Business Papers, Inc.

THE GAS WELDERS MONTHLY MAGAZINE

Acetylene Journal

Every day brings new information on the subject of gas welding. New uses for the torch, business-building kinks devised by shop proprietors and a hundred other things which help the welder.

Oxy-acetylene welding has its own publication in the ACETYLENE JOURNAL. All the news and developments of the day appear in its columns in the shape of helpful illustrated articles, news items and contributions by the "other fellow" which are helpful to you.

Several thousand welders read the Journal. Your name should be on our list. Just send in your name, address and one dollar bill ($1.00 per year in U. S. and Canada, $1.50 abroad) and you will insure a years interesting and profitable reading on YOUR trade.

Write for a sample copy for convincing proof that the Journal is indispensable to your business

H. W. COOK, EDITOR

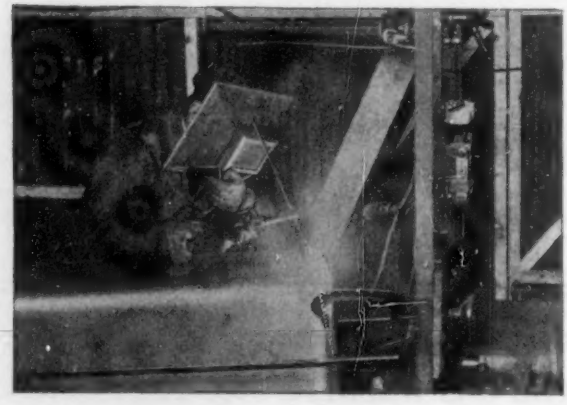
ACETYLENE JOURNAL

122 So. MICHIGAN AVENUE CHICAGO, ILL.

All books on welding may also be obtained through this office, including the famous "Autogenous Welding" by Granjon & Rosemberg (price $3.00) for which this office has the exclusive American rights.

LINCOLN ARC WELDER

Keeps A Steady Arc



The entire frame of the Lincoln Arc Welder is made up of laminations or sheets of steel instead of being made of a solid casting. The electrical man will readily understand that this permits a very rapid changing in the amount of magnetism or flux density and thus makes it possible for the voltage to adjust itself almost instantly to any demand.

In addition to the laminated steel frame the Lincoln Welder is provided with a stabilizer which acts on the electric current much like the flywheel on a piece of machinery. It stores up energy, permitting the machine to take care of any extraordinary demand without trouble.

The Lincoln Electric Company

General Offices and Factory

Cleveland, Ohio

The Lincoln Electric Co. of Canada, Ltd., Toronto Montreal

BRANCH OFFICES

New York City, Cincinnati, Pittsburgh, Buffalo, Detroit, Philadelphia, Charlotte, N. C., Fort Worth, Texas, Boston, Minneapolis, London, England, Los Angeles, Chicago

There is No Substitute
for Safety

REGO

Welding and Cutting Outfits
Are
SAFE

First Last and Always

Distributed Nationally By

Kentucky Oxygen Hydrogen Co.,	Logan St. & Goss Ave.,	Louisville, Ky.
Weldex Equipment Co.,	3 Millard Ave.,	N. Tarrytown, N. Y.
International Oxygen Co.,	796 Frelinghuysen Ave.,	Newark, N. J.
Gas Products Co.,		Columbus, Ohio.
Memphis Oxygen Co.,	682 So. Main St.,	Memphis, Tenn.
St. Paul Welding & Mfg. Co.,	174 W. Third St.,	St. Paul, Minn.
Acme Oxygen Co.,	431 So. Dearborn St.,	Chicago, Ill.
Welderaft Equipment Co.,	2723 Liberty Ave.,	Pittsburgt, Pa.
The Bastian-Blessing Co.,	125 W. Austin Ave.,	Chicago, Ill.

Essentials for Safe and Reliable Electric Arc Welding

WANAMAKER COATED ELECTRODES and TECOR ACCESSORIES

Write for Booklet

Transportation Engineering Corporation

15 PARK ROW
NEW YORK

220 SO. STATE STREET
CHICAGO

TORCHWELD Non Flash APPARATUS

FOR WELDING AND CUTTING OF METALS

Hand and Machine Torches in proper sizes for all Welding and Cutting requirements—

Acetylene Gas Generators. Gas Pressure Regulators. Lead Burning, Brazing, Soldering and Decarbonizing Outfits. Welding Supplies and Accessories.

TORCHWELD EQUIPMENT COMPANY

224 NORTH CARPENTER STREET, CHICAGO, ILLINOIS.

ACETYLENE FROM CAKES

Carbic low pressure, portable generator. Weight charged—200 lbs. Listed as standard by Fire Underwriters' Laboratories.

The most modern, efficient and safest source of acetylene supply—Carbic CAKES.

Not an experiment. Hundreds of Carbic generators using Carbic are in daily use on all kinds of welding and cutting work.

The use of Carbic Cakes permits an ease of handling, a convenience and a safety not otherwise obtainable.

Acetylene from Carbic costs less than one-half as much as compressed acetylene and only a few drums of cakes carried in stock insure a large supply of gas on hand at all times.

THE Carbic SYSTEM

CARBIC MFG., CO.

Duluth, Minn. New York, 141-149 Center St.
Boston, 27 School Street Chicago, 565 W. Wash. Blvd.
The Hendrie & Bolthoff Mfg. & Supply Co., Denver, Colorado.
Woodward, Wright & Company, New Orleans, La.

Offices and Representatives in other principal Cities.

PAGE-ARMCO
ELECTRODES

High grade welding equipment would be of little value without the use of pure welding metal.

Page-Armco Electrodes are the purest iron known commercially (99.84%). The impurities taken in the aggregate do no exceed 16/100 of 1% when considering silicon, sulphur, phosphorus, carbon, manganese, copper, oxygen, hydrogen and nitrogen.

Page-Armco Electrodes conform to the American Welding Society Specifications for Electrodes, Grade E-No. 1-A.

Blue tag — ends of rods colored blue.

Page Steel and Wire Company
Bridgeport, Connecticut

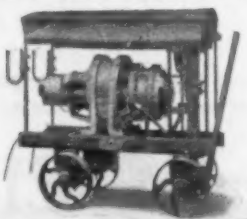
District Sales Offices:
Chicago New York Pittsburgh San Francisco

Manufacturers of

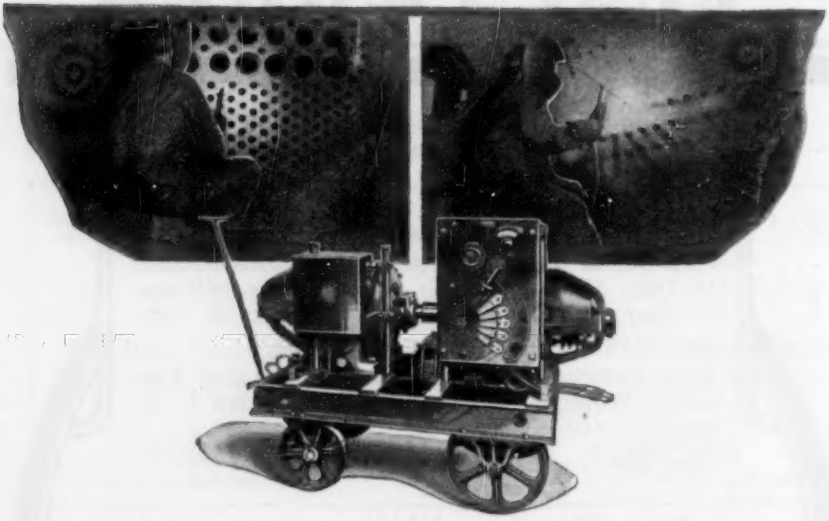
RODS—Armco Ingot Iron and Special Analysis Steels.

WIRE—Plain and Galvanized—Rope, Telephone, Telegraph, Bond, Strand, Oxy-Acetylene and Electric Welding Wire.

FENCE—Woven Wire for Farm and Railway Right of Way, Wire Link Protection for Industrial Plants, Lawns, Schools and Estates, and Factory Partitions.



Give Your Welders the Benefit of Good Equipment



The Purchaser of this G-E Arc Welding Set Writes:

"The Arc Welder which we purchased from you is indeed doing splendid work and the quality of work performed is beyond our expectations. In our locomotive firebox work it is doing wonders and I assure you that should we need any additional welding equipment in the future, which no doubt we will, that we will take up the matter with you at that time."

Signed:
Thomas McNally, President,
PITTSBURG BOILER AND MACHINE COMPANY,
Pittsburg, Kansas.

Bulletins describing G-E Welding Equipment and the Welding School sent on request. Write our nearest office.

General Electric Company

General Office Schenectady, N.Y.

Sales Offices in all large cities

43B-714D

PREST-O-LITE PRE-EMINENCE

THE result of sincere, unceasing effort, backed by the essentials of success, to establish and maintain purity of product and dependability of service, available *always* where there exist demands for dissolved acetylene--54 plants and warehouses *at your service*

Pittsburgh
Buffalo
Milwaukee
Chicago
Cleveland
Atlanta

Prest-O-Lite
DISSOLVED ACETYLENE

San Francisco
Dallas
Philadelphia
St. Louis
Boston
Detroit

THE PREST-O-LITE COMPANY, INC.
General Offices: Carbide and Carbon Building, 30 East 42nd Street.
New York
ADDRESS ANY DISTRICT SALES OFFICE LISTED ABOVE

Oxweld Can Do It!

A Slogan Built on Performance

OXWELD ACETYLENE COMPANY

NEWARK, N. J.
CHICAGO
SAN FRANCISCO

WORLD'S LARGEST MAKERS OF OXY-ACETYLENE EQUIPMENT

Before Purchasing Please INVESTIGATE!!

WILSON PLASTIC ARC WELDERS

AND

COLOR-TIPT WELDING METALS

Wilson Welder and Metals Co., 132 King St., New York

WELDING MILBURN OXY-ACETYLENE CUTTING

APPARATUS

is the result of research and development dating back to the infancy of the industry. The Milburn Line includes all sizes of Welding and Cutting Torches, Regulators and Generators.

THE ALEXANDER MILBURN COMPANY

1416-1428 W. Baltimore Street **Baltimore, Maryland**

ROEBLING WELDING WIRE

For

Electric Welding

Oxy-Acetylene (Gas) Welding

JOHN A. ROEBLING'S SONS CO

TRENTON, NEW JERSEY

Branch Stores and Warehouses

New York Boston Chicago Philadelphia Pittsburgh Cleveland Atlanta San Francisco Los Angeles Seattle Portland, Ore.

UNA Rail Bonds

A Path of Copper from Rail to Rail

The installation of UNA Rail Bonds is the simplest and quickest method of bonding. A weld of the all copper bond is made direct to the steel rails. In this way, copper alone carries the current from rail to rail. Thus maximum power savings result and the full value from bonding is obtained.

Investigate UNA Bonds now—they save money

RAIL WELDING & BONDING CO.
CLEVELAND, OHIO

Acetylene in Portable Cylinders for Oxy-Acetylene Welding and Cutting

Supplied in any quantities. Do you understand our free loan plan? If not, we are glad to explain.

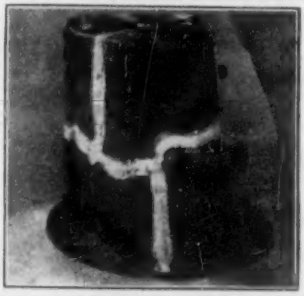
Supplied in the following sized cylinders.

10" x 30" size—capacity approx. 125 cu. ft.
12" x 36" size—capacity approx. 225 cu. ft.
12" x 44" size—capacity approx. 275 cu. ft.

Prompt and efficient service through plants and warehouses.

COMMERCIAL ACETYLENE SUPPLY CO., INC.
(Main Office) 80 BROADWAY, NEW YORK

BRANCHES:—
204 Trust Co. of Ga. Bldg., Atlanta, Ga.
540 So. Dearborn St., Chicago, Ill.
552 Monadnock Bldg., San Francisco, Cal.
18 Toronto St., Toronto, Ont., Canada.



ELECTRIC ARC WELDING

Are you welding cracked water jackets, crankcases and frames without dismantling.

The ALTERNARC will do it without preheating or warping and at a very low cost.

ELECTRIC ARC CUTTING & WELDING CO.

152 Jelliff Ave., Corner Avon Ave., Newark, N. J.
Telephone Waverly 7802-3

Service for New England on Welding Wire Requirements

ARMCO WELDING WIRE

In Boston Stock

FOR ELECTRIC WELDING
Armco Blue Label in 14 inch lengths.
On reels for G-E Automatic Welding Equipment.

FOR GAS WELDING
Armco Yellow Label in 36 inch lengths.
Also Cast Iron, Tobin Bronze, Alum, etc.

P. F. McDONALD & COMPANY

STEEL

17 KING TERMINAL — All Grades and Finishes — BOSTON 27, MASS.

THERMIT WELDING

Permanent Repairs of Heavy, Broken

Shafts — Housings
Crankshafts — Rolls and Pinions
Press Frames — Locomotive Frames

Thermit Welds in frame of Toggle Press.

Send for Pamphlet No. 1735

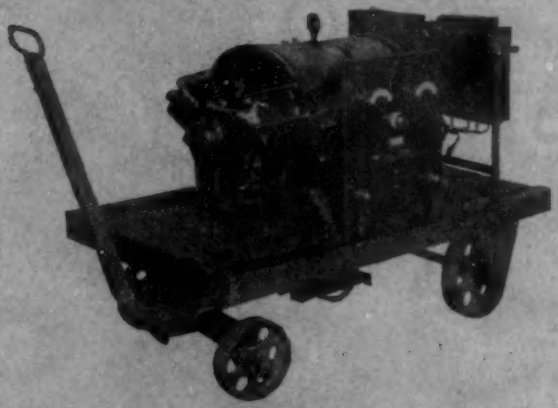
METAL & THERMIT CORPORATION

120 BROADWAY, NEW YORK

BOSTON PITTSBURGH CHICAGO TORONTO SOUTH SAN FRANCISCO

Electric Arc Welding
Equipments and Supplies

Properly designed and built to give dependable service with least attention.



SINGLE OPERATOR, VARIABLE-VOLTAGE TYPE, PORTABLE UNIT

We Invite Inquiries on All Matters Pertaining to Electric Arc Welding. Send for Bulletin No. 127

BURKE ELECTRIC CO.

Manufacturers of

ELECTRIC WELDING OUTFITS

and

ELECTRIC MOTORS AND GENERATORS FOR ALL PURPOSES.

Main Office and Works, Erie, Pa.

Service-Sales Offices

New York	*Detroit*	*Philadelphia*
Pittsburgh	*Cleveland*	*Buffalo*

AIRCO
DAVIS

ANYTHING AND EVERYTHING
For Oxyacetylene Welding and Cutting

SERVICE

Airco-Davis-Bournonville
No. 3700 Heavy Duty Welding Torch

SERVICE

Airco - Davis - Bournonville torches represent years of experiment and test. Their leadership has been strengthened with the passing of time.

Write for Airco Booklet:
"Anything and Everything for Oxyacetylene Welding and Cutting"

AIR REDUCTION SALES COMPANY

Manufacturer of Airco Oxygen and Airco Acetylene and other Airco and Airco-Davis-Bournonville products—Controls the Manufacture and Sale of National Carbide.

Home Office: 342 Madison Ave., New York, N. Y.

Airco District Offices, Plants and Distributing Stations conveniently located throughout the Country.

"Airco Oxygen and Acetylene Service is Good Service"